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PROJECT REPORT

Development of Wire Mesh Particulate Oxidizer Traps Using Fuel Additives for Diesel Emission Control in Mines

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SUMMARY

Oxidation of diesel exhaust gas and particulate emissions by filters and traps is expected to improve the atmospheres of underground mines. This paper discusses particulate oxidizer traps fabricated from steel mesh with two types of surface treatment used with and without fuel additives.

SOMMAIRE

L'oxidation des gas d'echapement et des particules suspendues dans les emissions, a cause des filtres, devrait ameliorer l'atmosphere des mines souterraines. Ce document discute les filters oxydantes fabricues d'une maille d'acier avec deux systems de traitement de surface, avec et sans des additives de combustible.

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OBJECTIVE

To develop and test exhaust treatment devices to remove toxic components from the exhaust products of diesel engines used in underground mines. The devices to be developed and tested are known as Particulate Oxidizer Traps (POT).

Primary objectives in the development of the POTs include:

a) efficient removal of particulate matter

b) backpressure meeting engine manufacturers' specifications

c) dimensions compatible with practical applications

d) on-vehicle capabilities.

Secondary objectives include:

a) physical robustness

b) ease of maintenance

c) adaptability to mine vehicle configurations

Regeneration is to be accomplished without the use of platinum group metal catalysts. Fuel additives to lower regeneration temperatures will be tested.

The basic trapping elements consist of a mesh of stainless steel strands. These elements will receive two types of surface treatment identified herein as Type I and Type II and/or POT I and POT II.

The ability of each type of surface treatment to meet the project objectives will be assessed.

BACKGROUND

The potentially harmful effects of exhaust products from diesel engines has been investigated by many authorities. In particular a Research and Development program of the Collaborative Diesel Research Advisory Panel (Panel) funded primarily by Canmet, USBM and the Ontario Ministry of Labour has:

a) identified many of the deleterious components

b) fostered development of devices to control such components

c) established quantifiable performance ratings for such devices.

From the technology developed through the Panel program a diesel particulate filter of ceramic material (DPF) has demonstrated the most promise of commercial application (1). DPFs have been shown to have good efficiency in particulate removal but there have been indications of a possible lack of resistance to both physical and thermal shock (2, 3, 4).

Any device in the exhaust train designed to collect particulates while passing gaseous emissions will result in increasing pressure drop through the device as the amount of particulate deposited increases with time. At some point the flow restrictions will create a backpressure which exceeds engine manufacturers' specifications; hence a filter or trap must be cleaned periodically before such back pressure is reached.

The particulate matter is chiefly carbonaceous and the obvious method of cleaning is to burn the 'soot' particles to regenerate the device.

There are many types of vehicles in underground mines which have different duty cycles. The Panel program has concentrated on load, haul, dump (LHD) vehicles powered by Deutz engines. Engine performance during LHD cycles has been approximated by computer modelling to facilitate laboratory investigation. Analyses of typical LHD operating cycles show the maximum average exhaust temperature to be expected is about 470° C.

Hydrocarbons collected from exhaust flows have a natural ignition temperature of about 450° to 500°C. Previous tests sponsored by the Panel and others have shown that the ignition temperature of these hydrocarbons may be lowered significantly by the use of certain metallic compounds. The metallic substances are either added to the fuel, often referred to as fuel additives, or bonded to the surface of the filter or trap, often referred to as catalysts. Ignition temperatures of the order of 350° C have been recorded with the use of these metallic compounds (5, 6, 7).

Some platinum group catalysts convert the sulphur in the fuel to SO_3 and thence to a sulphate, perhaps contributing to an H_2SO_4 acid mist.

Steel mesh substrate particulate traps previously tested have used platinum group catalysts to lower the regeneration temperature. However, questions concerning the quality of the environment with respect to the emissions of H_2SO_4 have been raised.

Because of the probable primary and secondary properties of steel substrate traps, further investigation of their capabilities without the presence of platinum group catalysts is of value to the mining industry and regulatory authorities.

The present POT evaluation employs steel mesh elements with two different surface treatments. It was anticipated that the POTs would:

a) regenerate on LHD cycles

b) regenerate at lower temperatures with fuel additives

c) efficiently store and remove particulate

d) emit little or no H_2SO_4.

The efficiency of the POT will be evaluated by comparison of test results and by calculating the Exhaust Quality Index (EQI). The EQI is a quantifiable performance index which can be used by mine operators and regulatory bodies to compare the effectiveness of exhaust conditioning devices.

DESIGN

Description

The function of the Particulate Oxidizer Trap -- POT -- system is the oxidation of trapped particulate and gases to gaseous products, principally CO_2 and water vapour, which are discharged from the trap.

For maximum versatility, a system is constructed from individual elements or blocks (fig. i) formed to fit together using the male and female registers into columns. The blocks are made from compressed knitted stainless steel ribbon. After formation into a toroidal mesh block, the ribbon is surface treated to reduce the void volume and increase the internal surface area. Gas flows radially inward through the mesh and exits from one or both ends of a column.

The choice of a POT to suit a particular engine requires a balance between entrapment, space limitations and back-pressure which will result in the specification of the total block requirement which can be divided into columns to suit the engine. The column(s) are mounted into suitable containers, or cans, to permit satisfactory gas-flow through the system. The cans become the exhaust manifold.

The physical construction and arrangement of the blocks does not allow a rigorous design calculation, but an examination of allowable engine exhaust flow characteristics can indicate an appropriate POT size.

Entrapment

Entrapment is achieved by the POT by impingement as the exhaust gas with entrained particulate flows radially through the elements. The relatively massive particulates, forced into contact with the mesh surfaces, adhere due to adsorbed hydrocarbons on the particulate surface. No attempt is made to predict entrapment level theoretically.

Operation of the trap is a complex function of exhaust gas velocity, radial thickness and void ratio of POT elements and size and size distribution of particulates. The physical characteristics of the blocks are relatively fixed while the size and distribution of emitted particulate vary with engine loads and speeds.

Initially, the trap will always collect particulate from the gas stream but a tendency for deposited particulate to be displaced from the trap can develop. Assuming no burnoff of the particulate, two conditions are possible:

(a) Collection rate exceeds removal rate, and the trap eventually plugs.

(b) Collection rate equals removal rate, and net entrapment becomes zero.

The mesh blocks have been selected to operate in condition (a) for initial radial gas velocities in the range 0 - 2 m/s. This permits investigation of trap regeneration uncomplicated by blow-off.

Back Pressure

Pressure loss across the POT system is the sum of three components, entrance, exit and friction losses through POT blocks. Entrance and exit losses can be small in comparison with the friction loss through the blocks. Pressure drop through the blocks, at a minimum when the system is fresh or particulate-free, will increase as particulate is collected.

It has been determined that ideally a regeneration of the POT should take place, artificially induced or spontaneously, before the back-pressure reaches about two and a half times its fresh level. If regeneration is delayed ignition of the additional mass of stored particulate may damage the POT by over-heating.

For the engine in this study, the manufacturer's specified maximum exhaust back-pressure is 750 mm water-column and is assumed to be distributed as follows:

exhaust system, excluding POT	150 mm
POT can entrance and exit	150 mm
POT elements	450 mm

As the engine has a V configuration the pressure drop across the fresh blocks should be about 225 mm wc or about 2 kPa.

Exhaust Gas Flow For Deutz F8L-413 F/W Engine

$$Q = \frac{Di}{1000} \times \frac{rpm}{2} \times \frac{Te + 273}{Ta + 273} \times 0.85$$

Where Q = exhaust gas flow (m^3/min)
Di = displacement (litres) = 12.81
rpm = 2300
Te = max exhaust temp. (^oC)
Ta = ambient temp (^oC)
0.85 = volumetric efficiency.

$$Q = \frac{12.8}{1000} \times \frac{2300}{2} \times \frac{(500+273)}{15+273} \times 0.85$$

$$= 33.6 \ m^3/min$$

Number of Blocks

Exhaust gas velocity is proportional to pressure loss

$P = KV^2$ where P = pressure drop - mm wc
V = superficial entrance gas velocity - m/s
K = empirical constant

and $V^2 = \frac{P}{K} = \frac{225}{800} = .28125$

and V = .53 m/s
= 31.82 m/min

Exhaust gas quantity is proportional to area and velocity

$Q = AV$ where Q = flow from Deutz F8L - m^3/min
V = gas velocity - m/min
A = surface areaof POT - m^2

and $A = \frac{Q}{V} = \frac{33.6}{31.8} = 1.057\ m^2$

Length of block column

$A = PiDL$ where D = .114 m
L = length of block column

and $L = \frac{A}{PiD} = \frac{1.057}{.114\ Pi}$

= 2.95 m

To accommodate V - 8 engine use two POTs of length $L/_2$ m

To accommodate exhaust geometry of Deutz F8L use two columns/POT of $L/_4$ m

where $L/_4$ = .738 m

As each block can be compressed to about 75 mm long, use 10 elements per column.

X X X X X X

Therefore the test installation was built incorporating two POTs, one on each engine bank, each POT containing two columns of 10 elements.

FABRICATION

A POT consisted of a steel container with inlet and outlet ports and two parallel columns of compressed steel mesh blocks. The inlet ports conformed to the exhaust manifold geometry of the Deutz F8L 413FW test engine. Six POTs were made but only two containers, one for the left and right cylinder banks.

As the POTs were fabricated solely for the purposes of this contract the steel materials were from either ECS inventory or readily available stock. The can itself was 12 ga 304 stainless; the endcaps, end flanges and port flanges were mild steel. One end cap was bolted so the can could be used with the Type I and II elements. The inlet port flanges were faced to suit the Deutz engine.

Stainless steel cruciform shaped supports maintained the columnar form of the elements and protected the center passage from collapse.

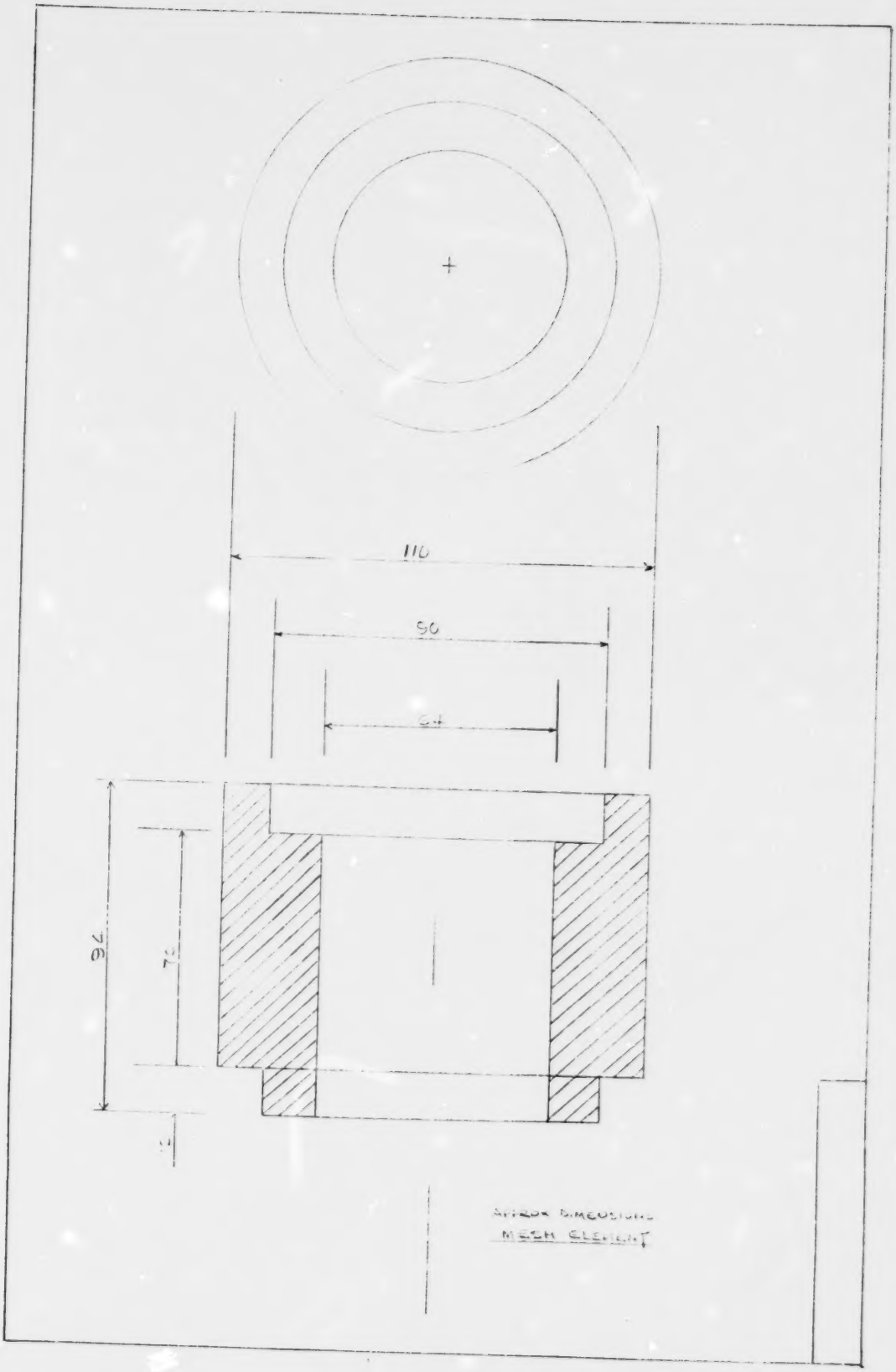
To accommodate normal manufacturing variances each element was weighed and measured and selected to make each column as similar as possible prior to compression. Elements were assembled in the can making sure the male and female registers mated. A load of about six tons applied by a hydraulic press compressed the columns.

The length of the column of uncompressed blocks is longer than the can. The maximum stroke of the available ECS press was about 14 inches required the column assembly to proceed in stages: compressing and decompressing until the last blocks were placed. The design column was achieved by four stages of compression and three of release.

Bolting the end cap to the shell maintained the compression of six tons.

Fittings to accomodate pressure and temperature sensors were located on the inlet and exit ports. These fittings were not symetrical with reference to the four inlet ports on each POT nor with the right and left hand configuration. Also, the fittings protruded into the can up to 1/4" except for the November tests.

To extract the elements after each series of tests at ORF a stabilizing pressure was exerted on the end cap. After bolt removal, the pressure was relaxed slowly and the elements allowed to expand. The degree of expansion observed was different for each column and there appeared to be no uniformity in any of the six POTs decompressed. No significant differences between POTs used on the right or left engine bank were observed. The expansion of the columns after removal of the end plate was between about 1/4" and 1 1/2".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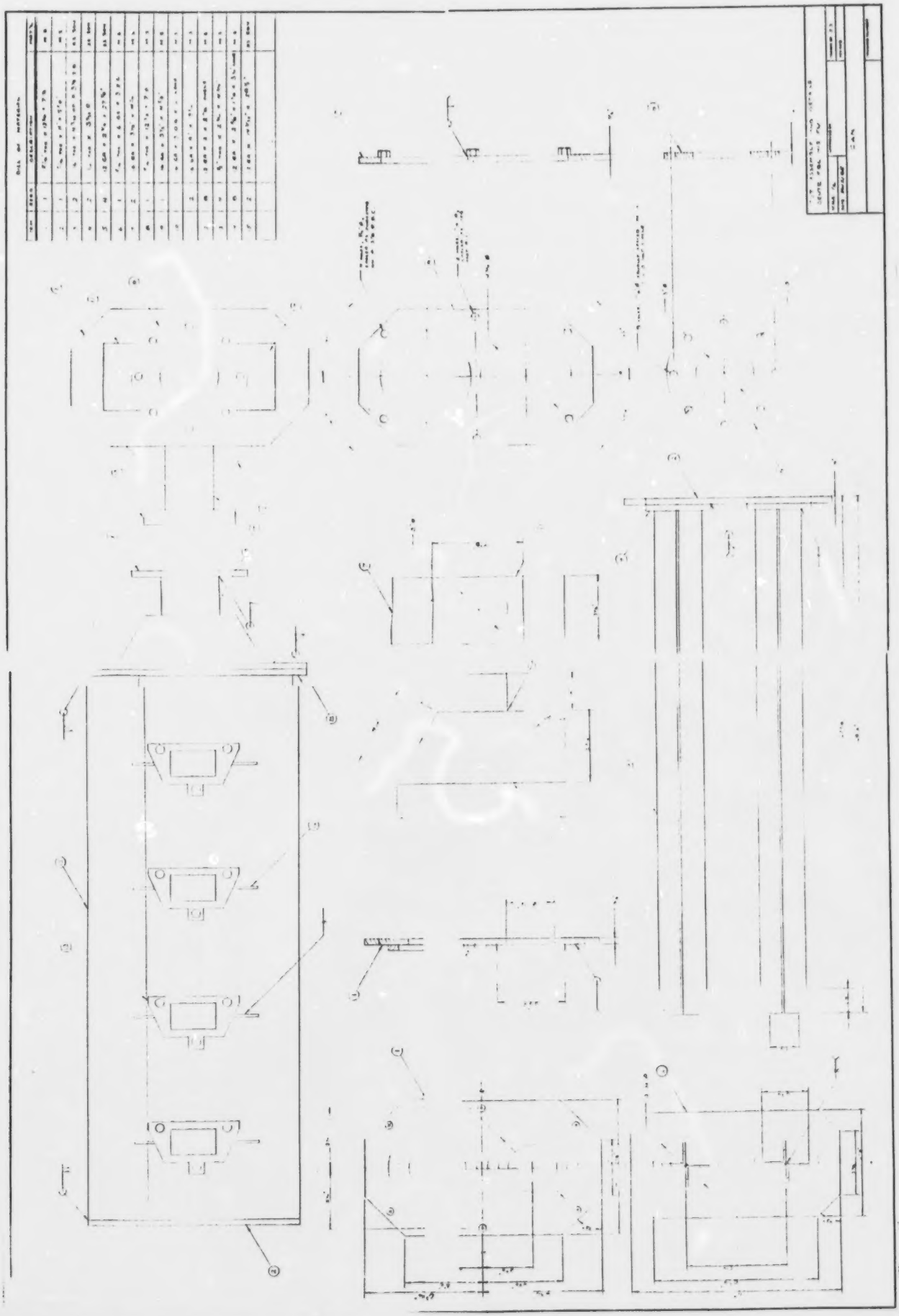


TEST RESULTS

A - Type I POTs

Chronology and summaries of the tests by ORF of the Type I POTs are shown in tables 14, 15 and 16. The tests conducted with the manganese based fuel additive in May resulted in the contamination and blockage of the elements due to a chemical reaction between the surface treatment and the fuel additive.

Visual examination of the contaminated blocks showed a chalk-like substance coating the wire and flakes blocking the mesh openings.

The elements were replaced in November and the POT retested with and without a cerium based fuel additive.

Data from both series of tests are included in this report.

Ignition Temperature

Lowest ignition temperature was obtained with the manganese based additive in the May 14th test, but accompanied by high backpressure. (See Table 1) Attempts to burn off the POT on May 31st following the unsuccessful Transient Cycle test produced high backpressures. (See Table 2) The elements were removed from the cans and the reaction products were discovered.

In the November tests, POT I with no fuel additive was tested over two cycles. The pressures obtained at regeneration were reasonable but the temperatures were relatively high. (See Table 3)

When the fuel was treated with the cerium based additive the ignition temperatures were reduced about 1% and the maximum backpressures were increased about 8 1/2%. (See Table 4)

In all three tests, the left bank pressures were lower than the right bank pressures by some 20% although the left bank temperatures were generally lower by less than 5%.

Average pressure buildup rates from initial to maximum for the three tests were about 1.6, 2.3 and 2.4 kPa/hour. The first rate came from fresh blocks.

Emissions

Emissions sampled in May from the contaminated traps are not considered significant and not recorded.

No emission samples were taken from the November Transient Cycle test as the POT did not regenerate.

Transient Cycle

The Type I POT Transient Cycle (MTU Mod 5) testing was done in May and November. Data are shown in Tables 10 and 11.

Tests in May, by the end of some 276 cycles, produced backpressures unacceptably high and no regeneration had taken place.

Tests in November using neat diesel fuel showed that the POT I did not regenerate under the pressure and temperature conditions of the MTU Mod 5 model. As noted previously the cerium based fuel additive did not significantly lower the ignition temperature. Hence successful regeneration during transient cycle tests with the additive was deemed unlikely to produce meaningful results.

B - Type II POTs

Tables 17 to 20 are summaries of the chronology, tests and emissions samplings of the Type II POT investigation program.

Ignition Temperature

Ignition temperature testing was carried out under five conditions of fuelling: neat diesel and two concentrations each of cerium based and manganese based fuel additives.Test data are shown in tables 5 to 9.

The highest ignition temperature, about 453° C was recorded with neat diesel fuel and the lowest, about 402° C was recorded using a dosage of 60 mg/L of Manganese. When the temperatures of the left and right manifolds were averaged, the difference between the highest and lowest regeneration temperatures was about 30°, less than 10%

The maximum pressures across the POT were between about 9.8 and 7.3 kPa on the left bank of the engine.

On the right bank the maximum pressures were between about 7.2 and 5.2 kPa with the neat diesel test showing about 5.4 kPa.

Average right bank pressure buildup rates from initial to maximum ranged from 0.9 kPa/hr for neat diesel to 1.2 kPa/hr for manganese.

Table 14

TEST PROGRAM CHRONOLOGY - POT I

Date 1985	Type of Test	Hours Tested Approx.	Fuel Additive Metallic Component	dosage ag/L
May 14	Ignition	4.50	Mn	80
22	Transient	7.50	Mn	80
23	Transient	.60	Mn	80
28	Transient	3.50	Mn	80
29	Transient	2.00	Mn	80
31	Ignition	2.25	Mn	80
Nov 22	Ignition	7.75	-	0
22	Transient	2.50	-	0
23	Transient	6.50	-	0
23	Ignition	2.80	Ce	90

Table 15

IGNITION TEMPERATURE TEST SUMMARY - POT I

Date	Fuel Additive Dosage	Pressure - DP - kPa Initial Left	Initial Right	MAXIMUM Left	MAXIMUM Right	Temperature at DP MAX. Left	at DP MAX. Right	Note
May 14	Mn-80	3.8	3.4	10.1	11.9	317	390	1
May 31	Mn-80	4.6	4.7	14.1	11.8	420	444	2
Nov 22	-	2.4	3.0	5.9	7.4	443	458	3
		3.0	4.1	5.8	4.6	441	458	
Nov 25	Ce-90	3.3	4.1	6.5	8.0	437	454	

NOTE:
1. These pressure readings may be total backpressure, not DP.
2. Unsuccessful attempts to regenerate after chemical contamination.
3. Two buildup and ignition cycles.

Table 16

TRANSIENT CYCLE TEST SUMMARY - POT I

Date	Fuel Additive Dosage	Test Hours	Test Cycles	Pressure - DP - kPa Initial Left	Initial Right	Maximum Left	Maximum Right	Note
May 22	Mn-80	5.8	134	5.9	6.7	7.2	7.0	1
May 23	Mn-80	.8	12					2
May 28	Mn-80	3.5	84	7.4	7.2	8.8	8.6	3
May 29	Mn-80	2.0	46	8.9	8.2	10.4	9.0	3
Nov 22	-	2.5	55	3.8	5.4	6.2	7.1	4
Nov 23	-	6.7	34	7.2	8.3	7.7	8.9	4

NOTE:
1. No significant regeneration.
2. Instrument problems.
3. Pressure increased with time.
4. No regeneration apparent.

Left and right refer to cylinders 1,2,3,4 and 5,6,7,8, respectively.
Temperatures are average of 4 cylinders
DP is differential pressure drop across POT
Maximum DP is assumed regeneration burn-off ignition point.

Table 17

TEST PROGRAM CHRONOLOGY - PDT II

Date 1985	Type Of Test	Hours Tested Approx.	Fuel Additive Metallic Component	dosage ag/L
Jul 15	Ignition	.9		
16	Ignition	4.4		
17	Ignition	.6		
17	Transient	6.5		
18	Transient	7.5		
19	Transient	4.5		
23	Transient	3.0		
24	Transient	5.1		
31	Ignition	3.0	Cerium	45
Aug 1	Ignition	3.5	Cerium	45
6	Ignition	.9	Cerium	90
7	Ignition	4.0	Cerium	90
8	Ignition	3.5	Manganese	80
12	Ignition	2.1	Manganese	60
13	Ignition	1.4	Manganese	60
13	Transient	1.4	Cerium	90
14	Transient	5.6	Cerium	90
15	Transient	4.1	Cerium	90
19	Transient	4.2	Cerium	90
23	Baseline		Cerium	90
27	Baseline			

Table 18

IGNITION TEMPERATURE TEST SUMMARY - PDT II

Date	Fuel Additive Dosage	Pressure - DP - kPa Initial Left	Initial Right	Maximum Left	Maximum Right	Temperature Deg C at DP Max Left	at DP Max Right	Note
Jul 15		1.8	1.9	2.3	2.0			
Jul 16		2.5	2.2	8.2	5.4	430	453	
Jul 31	Ce-45	2.3	2.2	3.6	2.8			1,2
Aug 1	Ce-45	3.4	2.6	9.8	7.2	412	432	
Aug 6	Ce-90	2.6	2.2	3.4	2.6			2
Aug 7	Ce-90	3.5	2.7	9.2	6.3	422	447	
Aug 8	Mn-80	2.8	2.3	7.3	5.4	400	419	
Aug 12	Mn-60	2.8	2.3	5.4	3.6	272	275	
Aug 13	Mn-60	5.1	3.4	9.0	6.1	397	421	

NOTE: 1. After burnoff at 100% torque
2. No temperatures recorded

Table 19

TRANSIENT CYCLE TEST SUMMARY - POT II

Date	Fuel Additive Dosage	Test Hours	Test Cycles	Pressure - DP - kPa Initial Left	Initial Right	Maximum Left	Maximum Right	Note
Jul 17	-	7.4	146	2.5	2.2	5.2	4.0	
Jul 18	-	7.6	180			6.0	4.7	1
Jul 19	-	4.7	104			7.3	4.6	1
Jul 23	-	3.1	54			4.3	5.2	1
Jul 24	-	5.0	120			8.4	5.7	1
Aug 13	Ce-90	3.4	18	2.7	2.4	3.2	2.8	
Aug 14	Ce-90	5.6	132			5.5	3.4	1
Aug 15	Ce-90	4.7	101			8.1	4.3	1
Aug 19	Ce-90	4.2	84	4.7	3.1	8.0	4.4	2

NOTE: 1. Initial pressure not recorded

2. After burnoff at 100% torque

Table 20

EMISSIONS SUMMARY - POT II

	BASELINE	FUEL ADDITIVE NONE	90 ag Cerium
GASEOUS-ppm			
CO	237	234	262
THC	122	74	79
NO	486	445	446
NO2	14	16	18
NOx	500	461	464
SULPHATES-ppm			
SO2 -theoretical		102	108
SO2		100	117
SO4		0	2
PARTICULATE-mg/m3			
Insoluble	95.8	37	26.9
Soluble	19.4	3	5
PASSTHROUGH-%			
Cerium	64		14

Transient Cycle

Two Transient Cycle (MTU Mod 5) test programs were run, one with neat diesel fuel and the other with 90 mg/L of cerium based fuel additive. Test data are in tables 12 and 13.

Although marginal regeneration was achieved, in general there was a buildup of backpressure during the duration of the test. Insufficient temperature data was recorded.

There was little significant difference between the regeneration achieved and the maximum pressures in the two tests conducted except, see Graphs 12 and 13, the rate of buildup in the right bank POT varied between neat diesel and the cerium additive.

One reason for the pressure differences between the end of one operating period and the beginning of the next is unrecorded engine running time.

Emissions

The results of emission testing of the Type II POTs with and without the 90 mg/L cerium additive were: 1) negligible variations in gaseous emissions, and 2) significant total particulate reductions. The percentage changes are shown in Table 22. Test data of particulate and sulphur emissions are shown in Tables 25 to 29 and test data for the gaseous emissions are in the appendix.

Ames tests of particulate samples from the POT II with neat diesel and with the cerium additive were negative and non-mutagenic for the salmonella tester strain TA-98 without metabolic activation. The baseline samples were positive and mutagenic. See appendix.

The POT II reduced the cerium passthrough. The baseline theoretical passthrough was about 64% of a theoretical concentration of 4.04 mg/m^3 and the passthrough with the POT in place was about 14% of a theoretical concentration of 4.93 mg/m^3.

DISCUSSION

The test engine was a Deutz F8L 413 FW, a V-8 configuration. It was not expected that temperatures and pressures from the left and right banks would be identical, but it was expected that they would be reasonably consistent.

Temperature data followed these expectations: the average of the readings at the four exhaust ports of the left bank was generally within 10% of the right bank.

Pressure data did not follow these expectations. During the ignition temperature tests the relationships between the left and right banks at maximum presure were:

POT I - spring	n/a
POT II - summer	left > right by 47%
POT I - fall	right > left by 26%

Similar results were observed during the transient cycle tests. Previous tests of traps with physically similar elements have not revealed this discrepanccy in presure drops between cylinder banks. (8, 9, 10)

These pressure variations cannot be reconciled from engine operating characteristics. They must be the result of physical differences between the POTs; at this time we do not know the reason.

The elements were checked on removal from the can for compression variation and columnar distortion. No significant physical phenomena were observed, as noted in the Fabrication section.

The higher presures exceeded the manufacturer's allowable, but the lower pressures, in general, were deemed acceptable.

The following discussion focuses on the acceptable, lower, pressures, regardless of which engine bank produced them. Temperatures are generally the average of both banks.

A - POT I

Average ignition temperatures for the three kinds of fueling tested with Type I POT were:

neat diesel	452° C
manganese additive	353° C
cerium additive	446° C

The low value achieved with the manganese additive was of no practical use because of the reaction between the surface treatment and the manganese.

The 452° with neat diesel was about the same as the low ignition point of the organic portion of the hydrocarbon "soot" exhaust product. The Type I surface treatment did not appear to contribute to any ignition temperature reduction.

We were disappointed in the lack of effectiveness of the cerium to promote lower ignition temperatures in conjunction with the POT I and hence did not test the POT - cerium combination over the transient MTU cycle.

Transient cycle tests of POT I with neat diesel fuel showed no spontaneous regeneration. The pressure increased at a rate of about 1 kPa/hour during the test without regeneration occurring. Before the end of the 3.7 hour test the pressures were greater than the manufacturer's allowable. Increased torque induced burnoff but the POT I did not regenerate.

As noted previously, no valid emission samples were obtained from the POT I test program.

B - POT II

The Type II surface treatment was selected to try to reduce the particulate ignition temperature by itself and in combination with fuel additives.

Average ignition temperatures and maximum pressures using five kinds of fuelling were:

neat diesel	442° C	5.4 kPa
45 mg/L cerium additive	422° C	7.2 kPa
90 " "	434° C	6.3 kPa
60 mg/L manganese additive	415° C	5.2 kPa
80 " "	412° C	5.6 kPa

Previous tests of manganese based fuel additives with ceramic filters had led to lower ignition temperatures. (5) It had been anticipated that POT II plus manganese would achieve ignition temperatures under 400° C; temperatures did not approach this value.

Ignition tests with manganese showed slightly lower temperatures and pressures than the other three kinds of fuelling. In the manufacture of the POT elements, Type I surface treatment was applied to all elements and the Type II treatment was added to those used for the POTs II. Hence, it was probable that some reaction between manganese and the Type I surface occurred with Type II POTs.

The cerium based additive is relatively new and according to the manufacturer, The Lubrizol Corporation, is still under development. Again, a significant reduction in ignition temperature did not occur. Backpressures with the cerium additive did not meet the engine manufacturer's standards. The pressure across the POT II for neat diesel can be deemed acceptable.

Initial pressure across the fresh POT II was about 1.9 kPa. After burnoffs during the ignition temperature tests readings in the order of 2.3 kPa were obtained.

If we define the ignition temperature as the temperature at which the quantity of particulate being trapped equals the quantity being oxidized, the pressure should remain constant under exhaust flows with appropriate temperatures. The DP vs time curves of ignition temperatures show this steady pressure.

The average exhaust temperature during one MTU Mod 5 cycle was calculated by ORF to be about 467° C. This is higher than the ignition temperatures recorded.

This cycle is different from the test cycle used for the CTO (9) and the results cannot be directly compared.

Pressure buildup in the right bank POT II for the transient tests with neat diesel showed a buildup rate over 22 hours of .14 kPa/hr. With cerium added the rate over 13 hours was about .16 kPa/hr. After the same running time, 13 hours, the pressure recorded for both kinds of fuelling was about 4.4 kPa. Table 21 records segmental and total pressure and time relationships.

Unassisted soot regeneration temperature varies between 450° and 500 ° C. Soot ignition temperature for POT II with neat diesel fuelling was defined about 417° under steady state conditions which is below the unassisted temperature. The MTU Mod 5 cycle average temperature is about 467° as calculated by ORF. The slow but steady buildup of backpressure suggests some temperature measurement irregularity associated with the transient cycle tests.

The lack of consistency in running time per shift, total running time and probable unrecorded running time makes comparisons of the two transient cycle tests difficult to interpret, but some of the pressures and rates are in reasonable agreement.

We do not know if the neat diesel pressure would have stabilized in the 5.7 kPa range or if the cerium test pressure would have reached the 5.7 kPa range. One anomaly with the cerium is the difference between the pressure at burnoff, 6.3 kPa in the ignition test and 4.9 kPa at hour 141.25.

Table 21

PRESSURE BUILDUP RATES

TRANSIENT CYCLE

POT II

FUELLING	RANGE OF DP - kPa	HOURS	RATE kPa/
neat diesel	2.6-4.0	5.7	.25
	4.2-4.7	6.5	.05
	4.6-4.4	3.5	- .06
	4.8-5.2	2.3	.17
	5.5-5.7	4.0	.05
	2.6-5.7	22.0	.14
90 ag/L cerium	2.3-2.5	.4	.50
additive	2.8-3.4	6.0	.10
	3.8-4.3	3.2	.16
	3.7-4.4	3.3	.21
	2.3-4.4	12.9	.16

Table 22

EMMISSIONS REDUCTION

POT II

	BASELINE	KIND OF FUELING			
		NEAT		CERIUM ADDED	
		EMMISSIONS	% CH	EMISSIONS	% CH
GASEOUS - ppm					
CO	237	234	- 1	262	+10
THC	122	74	-39	79	-35
NO	486	445	- 8	446	- 8
NO2	14	16	+14	18	+29
NOx	500	461	- 8	464	- 7
SULPHATES - ppm					
SO2	105*	100	0	117	+ 8
SO4		0		2	
PARTICULATES - ag/m3					
insoluble	96	37	-61	27	-72
soluble	19	3	-84	5	-74
total	115	40	-65	32	-72

*average theoretical based on fuel analysis

TABLE 23

EQI SUMMARY

	Baseline emission component		Neat Diesel emission component		90 ag/L Cerium emission component	
$\frac{CO}{50}$	230	4.6	234	4.7	262	5.2
$\frac{NO}{25}$	486	19.4	445	17.8	446	17.8
$\frac{RCD}{2}$	115	57.6	40	20.1	32	16.0
$1.5\left[\frac{SO2}{3}+\frac{RCD}{2}\right]$	104	138.4	100	80.2	117	82.5
$1.2\left[\frac{NO2}{3}+\frac{RCD}{2}\right]$	14	74.7	16	30.5	18	26.4
$\frac{H2SO4}{1}$	0	0	0	0	6.9	6.9
EQI		294.7		153.3		154.8
PARTICULATE CONTROL						
RCD		115		40.2		31.9
Efficiency				65%		72%

where CO, NO, NO2, SO2, are ppm
RCD, H2SO4 are in ag/am3

Table 24

AMES MUTAGENIC ACTIVITY SUMMARY

	Baseline	Neat Diesel	90 ag/L Cerium
Specific Activity	2.9	.9	1.8

Manganese additive was tested before the cerium but the engine was flushed for .5 hours at 100% torque between the two additives.

Table 22 summarizes the results of the emission tests.

There was little reduction of CO by POT II, as anticipated.

The POT II with cerium reduced the particulate emissions about 72% and the POT II with no additive about 60%. The particulate reduction with neat diesel is lower than anticipated and may be influenced by atmospheric temperature differences at the time of testing. The CTO tested over a cooler MTU cycle (9) reduced particulate emissions by about 85%.

There was no measured conversion of SO_2 to $SO_4^=$ with the neat diesel fuelling, but there was slight conversion when cerium was added. The amount was about half the sulphate produced by the CTO and about one fifth of that produced by a catalyzed ceramic trap. (10)

The sulphur related samples were collected in the afternoon of days with a difference in their maximum temperatures of less than 3^o C. The particulate samples for the neat diesel tests were collected in the morning of a day with minimum and maximum of about 10^o and 23^o; the cerium related samples in the afternoon with a maximum about 30^o.

The Exhaust Quality Index (EQI) was calculated from the formula in the Appendix used by Canmet. The reduction in the total EQI for POT II was about 45%. While this is a significant reduction of pollutants passing into the atmosphere, we hope that further refining of the POT II concept will result in greater reductions.

Table 23 shows there is little significant difference between the EQI of the two kinds of fuelling with the exception of the formation of H_2SO_4.

Physical Arrangement and Shock Resistance

The nature of the discreet elements and the ability to arrange them to suit the engine exhaust port geometry was discussed briefly in the Design and Fabrication sections.

The purpose-fabricated POT cans replaced the original exhaust manifolds for this project. Many mine vehicles will accomodate a similar arrangement. The POTs can also be located in the exhaust train at an advantageous location with respect to ease of mounting and access for maintenance.

The position of the blocks inside the container can be varied within the limits of exhaust gas flows to provide container dimensions adaptable to the shape and service requirements of mine vehicles.

Further investigation of potential cooling of the outer elements is indicated although observation after removal of the POTs showed little physical difference with respect to distance from the engine exhaust ports.

The inherent toughness and elasticity of the wire mesh blocks and the steel can resists damage from physical shock regardless of the service conditions under which a vehicle may operate. This robustness of the POT applies when the POT is mounted as a manifold or as part of the exhaust train.

Excellent thermal shock resistance by the wire mesh elements has been previously demonstrated. (9)

CONCLUSION

The Type I POT will not regenerate under the MTU-Mod 5 operating regime without fuel additives and the Type I surface treatment proved vulnerable to chemical reaction with metallic additives. The test results from this project showed the POT I does not meet essential criteria for an efficient diesel exhaust conditioning device.

Nevertheless the ignition temperature tests of POT I with no additives demonstrated that the steel wire mesh elements are an effective particulate trap.

The Type II POT without fuel additives achieved: reduction of noxious emissions; marginal regeneration on the MTU Mod 5 transient cycle -- +0.09 kPa/hour or +0.36 inches H_2O/hour at 467° C average temperature; reduction of soot ignition temperature -- 500° to 417°C based on steady state conditions; negligible H_2 SO_4 formation; reduced Ames mutagenic activity relative to baseline conditions; reduced EQI -- 295 to 153, a reduction of 48%; soot control efficiency of about 65%.

Two fuel additives did not materially enhance the operation of POT II as compared with no additives. The manganese based additive was found incompatible with POTs surface treatment and the cerium based additive did not produce significant benefits.

Consideration of the results from this project shows the POT II concept has demonstrated sufficient promise to warrant further investigation. The immediate need is to identify a method of qualitative and quantitative backpressure evaluation of the individual wire mesh elements.

We cannot recommend additional testing of POT II until adequate standards for element selection and performance are developed.

Research to develop such standards will be pursued so that the advantages of the POT II concept can be available to improve the underground environment of Canadian mines.

T E S T D A T A

Table 1

IGNITION TEMPERATURE

Pot Type I Fuel Diesel 40 Additive 80 ag/L Manganese

Test Date May 14, 1985

TIME			TEMPERATURES		BACKPRESSURE		ENGINE		NOTE
	minutes		Deg C average		DP - kPa		RPM	torque	
clock	elapsed	diff1	left	right	left	right		ft.lbs	1
0930	0	0					2200	131	
0935	5	5	266	281	3.8	3.4		131	
0940	10	5	264	280	4.3	3.7		131	
0945	15	5	264	280	4.6	4.0		131	
0950	20	5	265	280	4.8	4.1		131	
0955	25	5	266	281	5.0	4.3		131	
1000	30	5	266	281	5.1	4.4		131	
1005	35	5	266	281	5.2	4.5		131	
1010	40	5	265	286	5.4	4.7		131	
1020	50	10	267	285	5.6	5.0		131	
1030	60	10	267	287	5.8	5.3		131	
1040	70	10	267	287	6.1	5.6		131	
1050	80	10	267	288	6.3	6.0		131	
1100	90	10	267	285	6.5	6.3		131	
1110	100	10	268	286	6.8	6.7		131	
1120	110	10	268	286	7.0	7.1		131	
1130	120	10	269	287	7.2	7.4		131	
1140	130	10	271	290	7.4	7.9		131	
1145	135	5	271	290	7.6	8.2		131	
1150	140	5	291	314	7.8	8.5		158	
1155	145	5	292	315	8.0	8.7		158	
1200	150	5	293	315	8.2	9.1		158	
1205	155	5	312	335	8.4	9.5		188	
1210	160	5	310	339	8.6	10.1		188	
1215	165	5	308	339	8.8	10.3		188	
1220	170	5	312	364	9.2	10.8		215	
1225	175	5	312	365	9.5	11.3		215	
1230	180	5	321	377	9.8	11.7		240	
1235	185	5	317	390	10.1	11.9		240	
1240	190	5	334	417	10.1	11.5		268	
1245	195	5	334	419	9.9	11.3		268	
1250	200	5	335	419	9.8	11.3		268	
1255	205	5	333	418	9.8	11.3		268	
1300	210	5	338	429	9.8	10.9		274	
1305	215	5	343	428	9.8	10.8		274	
1310	220	5	345	427	9.7	10.6		274	
1315	225	5	346	433	9.5	10.4		280	
1320	230	5	352	431	9.4	10.3		280	
1325	235	5	360	431	9.3	10.2		280	
1335	245	10	378	451	8.2	9.2		295	
1345	255	10	377	452	7.8	8.6		295	
1350	260	5	405	481	7.1	7.4		320	
1355	265	5	249	295	6.4	6.4		131	
1400	270	5	236	296	6.9	7.1		131	

NOTE 1. Total backpressure, not DP

Table 2

IGNITION TEMPERATURE

Pot Type 1 Fuel Phillips No. 2 Additive 80 mg/L Manganese

Test Date May 31, 1985

TIME			TEMPERATURES		BACKPRESSURE		ENGINE		NOTE
	minutes		Deg C average		DP - kPa		RPM	torque	
clock	elapsed	diff1	left	right	left	right		Nm	
1030	0								
1055	25	25			4.6	4.8	2200	230	1
1110	40	15			5.7	5.5		230	
1115	45	5			6.4	6.0		230	
1120	50	5			6.8	6.3		230	
1125	55	5			7.3	6.6		230	
1130	60	5			7.8	7.1		230	
1135	65	5			8.3	7.4		230	
1140	70	5			9.0	7.9		230	
1345	195	125	281	297	7.6	6.4		230	
1350	200	5	298	304	8.8	7.6		230	
1355	205	5	316	320	9.9	8.4		257	
1400	210	5	320	332	10.4	8.9		257	
1405	215	5			11.2	9.4		271	
1410	220	5	338	357	11.9	10.1		284	
1415	225	5	347	365	12.8	10.7		290	
1420	230	5	367	386	13.5	11.3		325	
1425	235	5	420	444	14.1	11.8		380	
1430	240	5	420	444	14.0	11.6		400	
1435	245	5	421	446	14.0	11.5		400	
1440	250	5	423	447	13.9	11.5		400	
1445	255	5	435	460	13.6	11.1		414	
1450	260	5	433	462	13.1	10.7		414	
1455	265	5	433	464	12.8	10.6		414	
1500	270	5	433	464	12.5	10.4		414	
1505	275	5	435	464	12.3	10.3		414	
1510	280	5			4.7	5.0		230	
1515	285	5			4.7	5.0		178	

NOTE 1. Temperatures of first 70 minutes not recorded.

Table 3

IGNITION TEMPERATURE

Pot Type I Fuel Diesel 20% Additive none

Test Date November 22, 1985

TIME clock	minutes elapsed	minutes diff	TEMPERATURES Deg C average left	TEMPERATURES Deg C average right	BACKPRESSURE DP - kPa left	BACKPRESSURE DP - kPa right	ENGINE RPM	ENGINE torque Nm	NOTE
0930	0	0							
0945	15	15					2200	180	
0950	20	5			.3	.4		180	
0952	22	2			2.4	3.0		180	
0954	24	2			2.1	3.1		180	
0955	25	1			2.4	3.1		180	
1005	35	10			2.7	3.4		180	
1015	45	10	258	252	2.8	3.6		180	
1025	55	10			3.0	3.7		180	
1035	65	10			3.2	3.9		180	
1045	75	10			3.4	4.1		180	
1055	85	10	259	254	3.6	4.2		180	
1105	95	10			3.8	4.4		180	
1115	105	10			4.0	4.7		180	
1118	108	3			4.0	4.9		300	
1121	111	3	328	333	4.2	5.0		300	
1124	114	3			4.5	5.3		350	
1128	118	4	351	365	4.6	5.6		350	
1131	121	3			4.8	5.8		350	
1135	125	4			5.0	6.2		400	
1138	128	3	388	401	5.2	6.3		400	
1141	131	3			5.4	6.6		400	
1143	133	2			5.5	6.8		425	
1146	136	3	408	421	5.6	6.9		425	
1149	139	3			5.7	7.0		425	
1151	141	2			5.7	7.1		450	
1154	144	3			5.7	7.2		450	
1157	147	3	420	439	5.8	7.2		450	
1200	150	3			5.8	7.3		450	
1203 !	153	3	422	437	5.8	7.3		450	
1206	156	3			5.9	7.4		450	
1209	159	3			5.9	7.4		465	
1212	162	3	443	458	5.8	7.4		465	
1215	165	3			5.8	7.4		475	
1218	168	3	434	448	5.8	7.4		475	
1221	171	3			5.7	7.4		475	
1224	174	3			5.7	7.4		500	
1227	177	3			5.5	7.4		500	
1230	180	3	462	478	5.4	7.3		500	
1235	185	5	462	475	5.4	7.2		500	
1237	187	2			4.9	7.0		575	
1240	190	3			4.5	6.5		575	
1243	193	3	523	539	4.1	6.1		575	
1246	196	3			4.0	5.9		575	
1249	199	3			3.9	5.7		575	
1253	203	4	507	530	3.9	5.6		575	
1256	206	3			3.8	5.6		575	
1259	209	3			3.8	5.6		575	

Table 3, page 2

TIME clock	minutes elapsed	diff1	TEMPERATURES T - C average left	right	BACKPRESSURE DP - kPa left	right	ENGINE RPM	torque Nm	NOTE
1302	212	3			3.8	4.1		180	
1304	214	2			2.9	4.0		180	
1308	218	4			3.8	5.7		590	
1313	223	5			3.9	5.9		590	
1318	228	5			3.9	5.8		590	
1320	230	2			3.0	4.1		180	
1330	240	10			3.2	4.3		180	
1345	255	15			3.8	4.8		180	
1355	265	10	256	258	4.1	5.2		180	
1405	275	10			4.4	5.5		180	
1410	280	5			4.7	6.2		400	
1413	283	3	378	392	4.8	6.4		400	
1416	286	3			5.0	6.6		400	
1418	288	2			5.2	6.8		425	
1421	291	3			5.4	7.0		425	
1424	294	3			5.5	7.2		425	
1426	296	2	417	434	5.6	7.3		450	
1429	299	3	421	438	5.7	7.4		450	
1432	302	3	422	439	5.8	7.5		450	
1435	305	3	441	458	5.8	7.6		475	
1438	308	3	442	457	5.8	7.5		475	
1441	311	3	448	464	5.8	7.6		475	
1444	314	3	449	466	5.8	7.6		475	
1446	316	2	466	478	5.7	7.6		500	
1449	319	3	470	480	5.6	7.5		500	
1452	322	3	470	482	5.4	7.4		500	
1455	325	3			5.4	7.4		500	
1500	330	5	533	547	4.6	6.7		575	
1505	335	5			4.2	6.1		575	
1510	340	5			4.2	6.1		590	
1515	345	5			4.1	5.9		590	
1522	352	7			4.0	5.9		590	
1527	357	5			4.0	5.9		590	
1530	360	3			3.1	4.1		180	
1532	362	2			3.1	4.1		180	

Table 4

IGNITION TEMPERATURE

Pot Type I Fuel Diesel 20% Additive 90 mg/L Cerium

Test Date November 25, 1985

TIME clock	minutes elapsed	minutes diff'l	TEMPERATURES Deg C average left	TEMPERATURES Deg C average right	BACKPRESSURE DP - kPa left	BACKPRESSURE DP - kPa right	ENGINE RPM	ENGINE torque Nm	NOTE
1230	0	0							
1256	26	26					2200	590	
1300	30	4						590	
1301	31	1			5.1	7.1		590	
1310	40	9	536	552	4.5	6.2		590	
1318	48	8			3.3	4.1		180	
1325	55	7			3.5	4.3		180	
1335	65	10			3.8	4.6		180	
1345	75	10	265	267	4.1	4.8		180	
1355	85	10			4.4	5.1		180	
1359	89	4			4.8	5.8		350	
1404	94	5	353	370	5.1	6.2		350	
1407	97	3			5.3	6.5		350	
1410	100	3	385	403	5.6	6.8		400	
1413	103	3			5.8	7.2		400	
1417	107	4	417	438	6.0	7.6		450	
1420	110	3	418	439	6.2	7.8		450	
1423	113	3			6.3	7.9		450	
1426	116	3			6.3	7.9		475	
1429	119	3	442	456	6.4	7.9		475	
1432	122	3	441	453	6.3	8.0		475	
1435	125	3	438	454	/ 6.4	8.0		475	
1438	128	3	437	454	6.5	8.0		475	
1441	131	3	440	454	6.5	8.0		475	
1445	135	4	461	476	6.4	8.0		500	
1448	138	3	460	472	6.2	7.7		500	
1451	141	3	462	477	6.1	7.6		500	
1453	143	2			5.3	7.0		590	
1455	145	2			4.6	6.1		590	
1457	147	2	534	546	4.2	5.7		590	
1502	152	5			4.0	5.6		590	
1507	157	5			4.0	5.5		590	
1512	162	5			4.0	5.6		590	
1519	169	7	534	549	4.0	5.6		590	
1525	175	6			4.0	5.6		590	
1530	180	5			3.1	3.9		180	
1533	183	3			3.1	3.9		180	
1536	186	3			3.2	4.0		180	
1541	191	5	255	256	3.4	4.1		180	

Table 5

IGNITION TEMPERATURE

Pot Type II Fuel Diesel 20% Additive none

Test date July 15, 16, 1985

TIME			TEMPERATURE		BACKPRESSURE		ENGINE		NOTE	
	Minutes		Deg C average		DP -- kPa		RPM	torque		
clock	elapsed	diff'l	left	right	left	right		Nm		
1530	0									
1535	5	5					2200	180		0
1540	10	5			3.1			180	1	0
1541	11	1	271	281		3.0		180	1	2.71
1542	12	1			1.8			180		0
1543	13	1				1.9		180		0
1612	42	29	273	280	2.1			180		2.73
1613	43	1				2.0		180		0
1625	55	12				2.0	2260	180		0
1626	56	1			2.3			180		0
										0
0915	1065	1009					2200	180	4	0
0942	1092	27						180	2	0
0947	1097	5			2.5			180		0
0948	1098	1				2.2		180		0
0949	1099	1				3.4		180		0
0950	1100	1			3.8			180	1	0
1017	1127	27			2.8			180	1	0
1018	1128	1				2.3		180		0
1047	1157	29			3.2			180		0
1048	1158	1				2.6		180		0
1117	1187	29			4.1			180		0
1118	1188	1				3.1		180		0
1121	1191	3			4.2	3.2		180	3	0
1124	1194	3	282	288	4.4	3.2		180		2.82
1127	1197	3			4.4	3.3		180		0
1130	1200	3			4.5	3.3		180		0
1132	1202	2			4.6	3.4		200		0
1135	1205	3	294	300	4.7	3.4		200		2.94
1138	1208	3			4.8	3.5		200		0
1141	1211	3			4.9	3.6		200		0
1145	1215	4			5.1	3.7		250		0
1148	1218	3	324	332	5.3	3.8		250		3.24
1151	1221	3			5.4	3.8		250		0
1154	1224	3			5.6	3.9		250		0
1156	1226	2			5.7	4.0		275		0
1159	1229	3	336	347	5.9	4.1		275		3.36
1202	1232	3			6.1	4.2		275		0
1204	1234	2			6.2	4.3		300		0
1207	1237	3	353	364	6.4	4.4		300		3.53
1210	1240	3			6.8	4.5		300		0
1212	1242	2			6.8	4.6		325		0
1215	1245	3	369	382	7.1	4.7		325		3.69
1218	1248	3			7.3	4.8		325		0
1220	1250	2			7.4	4.9		350		0
1224	1254	4	392	406	7.6	5.0		350		3.92
1227	1257	3			7.9	5.2		375		0
1230	1260	3	407	427	8.1	5.4		375		4.07

Table 5, page 2

TIME			TEMPERATURE		BACKPRESSURE		ENGINE		NOTE	
	Minutes		Deg C average		DP --kPa		RPM	torque		
clock	elapsed	diff'l	left	right	left	right		Nm		
1232	1262	2			8.2	5.4		400		0
1235	1265	3			8.2	5.4		400		0
1238	1268	3			8.2	5.4		400		
1241	1271	3	430	453	8.1	5.3		400		
1243	1273	2	430	457	8.0	5.2		400		
1246	1276	3			7.9	5.2		400		
1249	1279	3			7.7	5.2		400		
1251	1281	2			7.2	5.0		450		
1254	1284	3	460	483	6.9	4.9		450		
1257	1287	3			6.6	4.8		450		
1301	1291	4			5.4	4.5		525		
1306	1296	5	527	554	4.6	3.7		525		
1311	1301	5			4.2	3.5		525	5	
1320	1310	9			3.7	3.0		500		
1330	1320	10			3.9	3.2		500		
1338	1328	8			3.4	2.9		180		
1341	1331	3			3.0	2.5		180		
1343	1333	2			2.9	2.4		180		
1425	1375	42							2	

NOTES:
1. Backpressure, not DP
2. Unrecorded running time
3. DP estimated; backpressure recorded by ORF
4. July 16
5. Engine overheating

Table 6

IGNITION TEMPERATURES

Pot Type II Fuel/Diesel 20% Additive 45 mg/L Cerium

Test Date July 31, Aug. 1, 1985

TIME clock	minutes elapsed	diff'l	TEMPERATURE Deg C average left	right	BACKPRESSURE DP - kPa left	right	ENGINE RPM	torque Nm	NOTE
1300	0	0							1
1315	15	15					2100	100%	
1330	30	15			3.8				
1340	40	10			3.4				
1345	45	5			3.2				
1350	50	5			3.1				
1355	55	5			3.0				
1400	60	5			2.9	2.7			
1405	65	5			2.9	2.7			
1410	70	5			2.9	2.7			
1415	75	5			2.3	2.2	2200	181	
1425	85	10			2.4	2.2		181	
1435	95	10			2.6	2.3		181	
1445	105	10			2.8	2.4		181	
1505	125	20			2.9	2.5		181	
1510	130	5			3.0	2.4		181	
1515	135	5			3.2	2.6		181	
1525	145	10			3.4	2.7		181	
1535	155	10			3.4	2.8		181	
1545	165	10			3.5	3.0		181	
1555	175	10			3.6	2.7		181	
1605	185	10			3.3	2.6		181	
0900	1200	1015					2200		2
0910	1210	10			3.4	2.6		185	
0915	1215	5			3.5	2.7		185	
0920	1220	5			3.6	2.8		185	
0925	1225	5			3.7	2.9		185	
0930	1230	5	269	275	3.8	3.0		185	
0940	1240	10	267	272	4.0	3.2		185	
0950	1250	10			4.3	3.3		185	
1000	1260	10	265	268	4.5	3.4		185	
1015	1275	15	263	268	4.8	3.6		185	
1025	1285	10			5.0	3.7		185	
1030	1290	5			5.1	3.8		185	
1040	1300	10	267	272	5.3	4.0		185	
1050	1310	10			5.5	4.1		190	
1100	1320	10	271	274	5.7	4.2			
1103	1323	3			5.8	4.2		200	
1107	1327	4			5.9	4.3		200	
1110	1330	3	281	283	6.0	4.4		200	
1114	1334	4			6.0	4.5		230	
1118	1338	4			6.2	4.5		230	
1123	1343	5	296	299	6.4	4.6		230	
1125	1345	2			6.5	4.7		250	
1130	1350	5	304	308	6.5	4.8		250	
1132	1352	2			6.8	4.8		275	

Table 6, page 2

TIME clock	minutes elapsed	diff'l	TEMPERATURE Deg C average left	right	BACKPRESSURE DP - kPa left	right	ENGINE RPM	torque Nm	NOTE
1135	1355	3	322	327	6.8	5.0		275	
1140	1360	5			7.1	5.1		275	
1145	1365	5			7.3	5.2		300	
1148	1368	3	348	354	7.8	5.5		300	
1151	1371	3			8.0	5.6		300	
1153	1373	2			8.2	5.8		325	
1155	1375	2	363	377	8.4	5.9		325	
1158	1378	3			8.7	6.1		325	
1200	1380	2			8.8	6.3		350	
1203	1383	3	377	394	9.1	6.5		350	
1205	1385	2			9.2	6.7		350	
1207	1387	2			9.3	6.8		375	
1210	1390	3	396	417	9.5	7.0		375	
1212	1392	2			9.6	7.1		400	
1215	1395	3	412	432	9.7	7.1		400	
1218	1398	3			9.8	7.2		400	
1221	1401	3			9.8	7.2		425	
1223	1403	2			9.7	7.0		425	
1225	1405	2			9.6	6.8		425	
1228	1408	3	429	450	9.5	6.7		425	
1230	1410	2			9.3	6.6		425	
1232	1412	2			9.3	6.5		425	
1233	1413	1			8.7	6.2		475	
1235	1415	2			8.4	5.8		475	
1237	1417	2	545	560	4.1	3.3		600	
1240	1420	3			3.0	2.6			

NOTE: 1. RPM hunting during complete test
2. Aug. 1

Table 7

IGNITION TEMPERATURES

Pot Type II Fuel Diesel 20% Additive 90 ag/L Cerium

Test Date 6, 7, Aug, 1985

TIME clock	minutes elapsed	minutes diff'l	TEMPERATURE Deg C average left	TEMPERATURE Deg C average right	BACKPRESSURE DP - kPa left	BACKPRESSURE DP - kPa right	ENGINE RPM	ENGINE torque Nm	NOTE
1530	0	0							
1540	10	10					2240	181	
1545	15	5			2.6	2.2		181	
1550	20	5			2.7	2.2		181	
1600	30	10			2.9	2.4		181	
1610	40	10			3.1	2.4		181	
1620	50	10			3.2	2.5		181	
1630	60	10			3.4	2.6		181	
0830	1020	960							Aug. 7
0840	1030	10			3.5	2.7			
0850	1040	10			3.8	2.9			
0900	1050	10			4.0	3.0			
0910	1060	10			4.2	3.1			
1000	1110	50			4.8	3.4			
1010	1120	10			5.1	3.6			
1030	1140	20			5.7	3.8			
1040	1150	10			6.0	4.0			
1100	1170	20			6.7	4.4			
1105	1175	5	334	342	6.6	4.3		300	
1108	1178	3			6.8	4.4		300	
1112	1182	4	339	346	6.9	4.7		300	
1116	1186	4			7.5	4.9		325	
1120	1190	4			7.9	5.2		325	
1123	1193	3			8.2	5.3		325	
1125	1195	2	394	415	8.3	5.6		375	
1130	1200	5			8.7	5.8		375	
1133	1203	3	394	415	8.9	6.0		375	
1135	1205	2	408	433	9.0	6.1		400	
1138	1208	3	411	436	9.0	6.1		400	
1140	1210	2			9.2	6.1		400	
1150	1220	10	410	430	9.2	6.2		400	
1152	1222	2			9.2	6.3		415	
1155	1225	3	422	447	9.2	6.3		415	
1200	1230	5	421	447	9.1	6.1		415	
1205	1235	5	423	449	8.9	6.1		415	
1210	1240	5	433	460	8.8	5.9		425	
1215	1245	5	432	459	8.5	5.7		425	
1217	1247	2			5.2	3.8		590	
1220	1250	3	548	563	3.3	2.7		590	
1225	1255	5			2.9	2.5		590	

Table 8

IGNITION TEMPERATURES

Pot Type II Fuel: Diesel 20% Additive: 80 ag/L Manganese

Test Date August 8, 1985

TIME clock	minutes elapsed	diff'l	TEMPERATURE Deg C average left	right	BACKPRESSURE DP - kPa left	right	RPM	torque Nm	NOTE
0930	0	0							
0940	10	10			2.8	2.3	2250	181	
0950	20	10			3.1	2.5		181	
1000	30	10			3.3	2.6		181	
1015	45	15	286	295	3.5	2.8		181	
1030	60	15	287	293	3.8	3.0		181	
1045	75	15			4.2	3.2		181	
1100	90	15	296	304	4.6	3.5		181	
1115	105	15			4.9	3.7		181	
1118	108	3			5.0	3.8		181	
1124	114	6			5.1	3.8	2250	181	
1126	116	2	316	322	5.0	3.7	2220	250	
1130	120	4	322	326	5.1	3.9		250	
1135	125	5	322	327	5.5	4.0		250	
1137	127	2	342	349	5.5	4.1		275	
1140	130	3			5.6	4.2		275	
1145	135	5	342	349	5.8	4.3		275	
1147	137	2			6.0	4.4		300	
1150	140	3	360	373	6.1	4.5	2250	300	
1156	146	6			6.3	4.7		300	
1158	148	2	372	384	6.4	4.8	2230	325	
1200	150	2			6.6	4.8		325	
1206	156	6	372	382	6.7	5.1		350	
1210	160	4			6.8	5.1		350	
1215	165	5	389	405	7.0	5.3		350	
1220	170	5	391	406	7.2	5.4		350	
1222	172	2	400	419	7.2	5.4		375	
1225	175	3			7.3	5.2		375	
1230	180	5	404	424	7.2	5.1		375	
1235	185	5			7.3	5.2		375	
1238	188	3			7.2	5.0		400	
1240	190	2	427	447	7.1	4.9		400	
1245	195	5			6.9	4.6		400	
1250	200	5	424	440	6.9	4.6		400	
1255	205	5	444	466	6.2	4.1		425	
1300	210	5			5.5	3.7		425	
1305	215	5			3.1	2.4	2100	600	

Table 9

IGNITION TEMPERATURES

Pot Type II Fuel Diesel 20% Additive 60 mg/L Manganese

Test Date August 12, 13, 1985

TIME clock	minutes elapsed	diff'l	TEMPERATURES Deg C average left	right	BACKPRESSURE DP - kPa left	right	ENGINE RPM	torque Nm	NOTE
1330		0							
1358	28	28			2.8	2.3	2250	181	
1400	30	2			2.8	2.3		181	
1405	35	5			2.9	2.3		181	
1415	45	10			3.1	2.5		181	
1430	60	15	274	280	3.4	2.6		181	
1445	75	15			3.8	2.8		185	
1500	90	15	275	280	4.1	3.0		185	
1515	105	15			4.5	3.2		185	
1530	120	15	276	281	4.9	3.4		185	
1545	135	15	272	275	5.4	3.6		185	
1600	150	15							
0930	1050	900							Aug 13
0942	1062	12							
0950	1070	8			5.1	3.4	2200	181	
1000	1080	10	276	279	6.0	3.9		181	
1004	1084	4			6.3	4.3		250	
1007	1087	3	320	330	6.5	4.5		250	
1009	1089	2			6.8	4.7		300	
1011	1091	2			7.1	4.8		300	
1013	1093	2	348	364	7.2	5.1		300	
1016	1096	3			7.4	5.2	2240	325	
1018	1098	2			7.6	5.4		325	
1020	1100	2	365	383	7.9	5.5		325	
1022	1102	2			8.1	5.6	2240	350	
1024	1104	2			8.3	5.8		350	
1026	1106	2			8.5	5.8		350	
1030	1110	4	385	404	8.8	6.0		350	
1033	1113	3			8.8	6.1	2250	375	
1035	1115	2			9.0	6.1		375	
1037	1117	2	397	421	9.0	6.0		375	
1040	1120	3			8.8	5.8		375	
1042	1122	2	401	426	9.1	5.8		375	
1044	1124	2			9.1	5.8		375	
1046	1126	2	404	430	9.1	5.7		375	
1048	1128	2			9.1	5.6		375	
1050	1130	2			9.0	5.4	2270	400	
1052	1132	2	423	454	8.7	5.2		400	
1054	1134	2	422	453	8.4	4.8		400	
1056	1136	2			8.2	4.7		400	
1058	1138	2			4.6	3.1	2100	100%	
1100	1140	2			2.9	2.5		100%	
1105	1145	5			2.7	2.4		100%	
1107	1147	2	551	563		2.4		100%	

Table 10

TRANSIENT CYCLES

Pot Type I Fuel Diesel 40 & Phillips D-2 Additive 80 ug/L Manganese

Test Date May 22, 23, 28, 29, 1985

TIME			CYCLES	BACKPRESSURE		TEMPERATURES	
24 hour clock	hours elapsed	diff'l	cum	DP kPa left	right	Deg C left	average right
0900	.00	.00	0				
0901	.03	.03	0				
0914	.24	.22	5		6.7		
0927	.45	.21	10	5.9			
0944	.74	.29	17		6.5		
0957	.94	.20	22	6.4			
1004	1.06	.12					
1011	1.19	.13	25		6.7	418	
1021	1.36	.17	29	6.3			
1031	1.52	.16	33		6.7		
1041	1.69	.17	37	6.2			
1100	2.00	.31					
1108	2.12	.12	40		6.9		456
1118	2.29	.17	44	6.4			
1128	2.46	.17	48		6.8		
1138	2.63	.17	52	6.4			
1148	2.80	.17	56		6.8		
1158	2.96	.16	60	6.5			
1258	3.96	1.00					
1305	4.08	.12	63		7.4		
1315	4.25	.17	67	6.9			
1325	4.42	.17	71		6.9		
1335	4.59	.17	75	6.8			
1345	4.75	.16	79		6.8		
1355	4.91	.16	83	6.8			
1404	5.06	.15					
1417	5.27	.21	88		6.9		
1427	5.44	.17	92	7.0			
1442	5.69	.25	98		6.3		
1452	5.86	.17	102		6.2		
1501	6.02	.16	106	6.9			
1512	6.20	.18					
1525	6.41	.21	111		6.8		
1535	6.58	.17	115	7.2			
1552	6.87	.29	122		6.9		
1602	7.04	.17	126	6.9			
1612	7.21	.17	130		7.0		
1622	7.37	.16	134	6.9			
1633	7.55	.18					
1030	25.50	17.95					
1043	25.71	.21	139	6.9			
1045	25.75	.04	140				
1100	26.00	.25	146		6.9		
1118	26.30	.30					

TIME			CYCLES	BACKPRESSURE		TEMPERATURES	
24 hour clock	hours elapsed	diff'l	cum	DP kPa left	right	Deg C left	average right
1300	148.00	121.70					
1301	148.02	.02					
1309	148.15	.13	149	7.4			
1324	148.40	.25	155		7.2		
1325	148.42	.02					472
1335	148.57	.15	159	7.3			
1350	148.82	.25	165		7.8		
1400	148.99	.17	169	7.5			
1427	149.45	.46	180		8.1		
1437	149.62	.17	184	7.9			
1454	149.91	.29	191		8.0		
1514	150.24	.33	199	8.1			
1524	150.41	.17	203		8.2		
1534	150.57	.16	207		8.6		470
1551	150.86	.29	214	8.7			
1601	151.03	.17	218		8.4		
1621	151.36	.33	226	8.8			
1631	151.53	.17	230		8.4		
1636	151.61	.08					
0830	167.50	15.89					
0856	167.93	.43					
0908	168.14	.21	235				
0918	168.31	.17	239	8.9			
0931	168.52	.21	244		8.2		
0941	168.69	.17	248	9.5			
0953	168.89	.20	253		8.8		
1008	169.14	.25	259	9.6			
1021	169.34	.20	264		8.3		
1031	169.51	.17	268	10.3			
1041	169.68	.17	272		9.0		
1051	169.85	.17	276	10.4			
1058	169.97	.12					

Table 11

TRANSIENT CYCLE

Pot Type I Fuel Diesel 2X Additive none

Test Date Nov. 22, 23, 1985

TIME clock	hours elapsed	hours diff'l	CYCLES cum	BACKPRESSURE DP - kPa left	BACKPRESSURE DP - kPa right	TEMPERATURE Deg C left	TEMPERATURE Deg C average right	NOTE
1530	.00	.00		4.4	5.2			4
1532	.03	.03		4.3	5.1			
1535	.08	.05	0					
1548	.29	.21	5	3.8				
1603	.54	.25	11		5.4			
1620	.83	.29	18	4.6				
1703	1.54	.71	35		6.4			
1720	1.83	.29	42	5.4				
1735	2.08	.25	48		7.1			
1752	2.38	.30	55	6.2				5
1755	2.43	.05		5.6				
1756	2.45	.02			6.9			1
1800	2.52	.07		5.9				
1802	2.54	.02			7.1			
1806	2.61	.07			7.7			
1807	2.62	.01		6.7				
0800	16.50	13.88						2
0811	16.68	.18						
0815	16.75	.07		7.2	8.3			1
0817	16.78	.03		7.7	8.7			
0820	16.83	.05						
0822	16.87	.04	56		8.9	412		
0832	17.04	.17	60		8.7	419		
0840	17.16	.12	63	7.4		418		
0850	17.33	.17	67		8.6	417		
0908	17.62	.29	74	7.3		418		
0920	17.83	.21	79	7.5			434	
0935	18.08	.25	85		8.9		434	
0944	18.24	.16	89	7.7			435	
1001	18.52	.28		8.2	10.6			3
1004	18.57	.05		6.7	8.8			
1007	18.62	.05		6.1	8.1			
1010	18.67	.05		5.3	7.4	532	549	
1015	18.75	.08		4.9	6.9			
1020	18.83	.08		4.7	6.6			
1025	18.91	.08		4.7	6.5			
1030	18.99	.08		4.6	6.4			
1040	19.16	.17		4.5	6.4	527	546	
1050	19.33	.17		4.4	6.3			
1100	19.50	.17		4.4	6.3			
1104	19.57	.07		4.3		464	476	
1109	19.65	.08		3.6	4.8			1
1111	19.68	.03		3.6	4.7	264	264	
1113	19.71	.03		3.6	4.8			
1134	20.06	.35						
1137	20.11	.05		3.7				
1140	20.16	.05		3.8	5.0			

TIME clock	hours elapsed	hours diff'l	CYCLES cum	BACKPRESSURE DP - kPa left	BACKPRESSURE DP - kPa right	TEMPERATURE Deg C average left	TEMPERATURE Deg C average right	NOTE
1150	20.33	.17		4.2	5.5			
1200	20.50	.17		5.2	7.1			3
1205	20.58	.08		4.9	6.9			
1210	20.66	.08		4.7	6.7	536	552	
1215	20.74	.08		4.6	6.6			
1225	20.91	.17		4.4	6.4			
1235	21.08	.17		4.3	6.4			
1245	21.25	.17		4.2	6.2			
1305	21.58	.33		4.2	6.2			
1328	21.96	.38		4.2	6.2	535	544	
1338	22.13	.17		4.3	6.3			
1348	22.30	.17		4.3	6.3			
1358	22.47	.17		4.2	6.2			
1415	22.75	.28		4.5	6.6			
1425	22.92	.17		4.5	6.5			
1430	23.00	.08		4.5	6.5			
1435	23.08	.08		4.4	6.5			
1440	23.16	.08		3.5	4.6			1
1453	23.38	.22		4.2	5.3			

NOTES
1. 2200 RPM, 180 Na.
2. November 23.
3. 2100 RPM, 100I
4. Ignition temperature tests until 15:27.
5. No temperature data shown by ORF for cycles 0-55.

Table 12

TRANSIENT CYCLE

POT Type II Fuel Diesel 20% Additive none

Test Date July 17, 18, 19, 23, 24, 1985

TIME			CYCLES	BACKPRESSURE DP - kPa		TEMPERATURE Deg C average		NOTE
	hours							
clock	elapsed	diff'l		left	right	left	right	
0900	.00	.00						1
0924	.40	.40						
0926	.43	.03		4.0	2.8			
0930	.50	.07		4.5	3.1			2
0935	.58	.08		3.9	3.0			
0940	.66	.08		3.4	2.8			
0943	.71	.05		3.2	2.7			
0946	.76	.05		3.0	2.7			
0949	.81	.05		2.9	2.6			
0952	.86	.05		2.6	2.4			1
0955	.91	.05		2.4	2.2			
0958	.96	.05		2.5	2.2			
1005	1.08	.12	0					
1018	1.29	.21	5	2.9				
1035	1.58	.29	12		2.6			
1050	1.83	.25	18	3.4				
1105	2.08	.25	24		2.9			
1120	2.33	.25	30					
1135	2.58	.25	36	3.9				
1150	2.83	.25	42		3.2			
1207	3.12	.29	49	4.2				
1222	3.37	.25	55		3.4			
1237	3.62	.25	61	4.5		431		
1252	3.87	.25	67		3.6	432		
1307	4.12	.25	73	4.7			454	
1322	4.37	.25	79		3.7		458	
1337	4.62	.25	85	4.8			457	
1405	5.08	.46	96		3.8		460	
1422	5.37	.29	103	4.9			459	
1439	5.66	.29	110		3.9		459	
1454	5.91	.25	116	5.0				
1509	6.16	.25	122		4.0			
1524	6.41	.25	128	5.1				
1539	6.66	.25	134		4.0			
1554	6.91	.25	140	5.2				
1609	7.16	.25	146		4.0		460	
1624	7.41	.25		4.9	4.0			1
1627	7.44	.03		4.8	3.8			
0900	24.00	16.56						3
0906	24.10	.10						
0921	24.35	.25	152	5.9			455	
0936	24.60	.25	158		4.2	432		
0951	24.85	.25	164	5.7		437		
1006	25.10	.25	170		4.2	432		
1023	25.39	.29	177	5.8				
1043	25.72	.33	185		4.2			
1100	26.00	.28	192	5.8				

TIME			CYCLES	BACKPRESSURE DP - kPa		TEMPERATURE Deg C average		NOTE
	hours							
clock	elapsed	diff'l		left	right	left	right	
1115	26.26	.26	198		4.3			
1130	26.51	.25	204	5.8		436		
1147	26.80	.29	211		4.3	435		
1204	27.09	.29	218	5.9			462	
1222	27.38	.29	225		4.4			
1237	27.63	.25	231	5.8			459	
1252	27.88	.25	237		4.4		464	
1309	28.17	.29	244	5.8				
1324	28.42	.25	251		4.5			
1342	28.71	.29	258	5.9				
1357	28.96	.25	264		4.6		462	
1412	29.21	.25	270	6.0				
1427	29.46	.25	276		4.6		467	
1442	29.71	.25	282	6.0		443		
1500	30.00	.29	289		4.6	442		
1530	30.50	.50	301	6.0		441		
1547	30.79	.29	308					
1604	31.08	.29	315		4.7	440		
1627	31.46	.38	324			432		
1632	31.54	.08	326					
1636	31.60	.06						4
1637	31.62	.02		5.6	4.6			1
1640	31.67	.05		5.7	4.6			
1030	49.50	17.83						5
1040	49.67	.17						
1053	49.88	.21	331	7.0		441		
1108	50.13	.25	337		4.6	444		
1123	50.38	.25	343	6.2				
1138	50.63	.25	349		4.4	445		
1153	50.88	.25	355	6.3		446		
1213	51.21	.33	363		4.4		472	
1230	51.50	.29	370	6.0			474	
1245	51.75	.25	376		4.3		474	
1305	52.08	.33	384	5.6				
1328	52.46	.38	393		4.3			
1345	52.75	.29	400	5.8			475	
1400	53.00	.25	406		4.3		471	
1415	53.25	.25	412	5.8				
1440	53.67	.42	422		4.4			
1455	53.92	.25	428	5.9			473	
1500	54.00	.08	430					
1504	54.07	.07		5.4	4.3			1
1506	54.10	.03		5.3	4.2			
1520	54.33	.23						6
0930	144.50	90.17						7
0955	144.92	.42						
1007	145.12	.20						8
1014	145.24	.12	433	7.3			446	9

TIME clock	hours elapsed	hours diff'l	CYCLES	BACKPRESSURE DP - kPa left	BACKPRESSURE DP - kPa right	TEMPERATURE Deg C average left	TEMPERATURE Deg C average right	NOTE
1022	145.37	.13	436		4.9		447	
1032	145.54	.17	440	7.1			448	
1039	145.66	.12	443		4.7		449	
1047	145.79	.13	446	7.0			450	
1102	146.04	.25	452		4.9	418		
1119	146.33	.29	459	7.0				
1154	146.91	.58	473		5.0			
1211	147.20	.29	480	7.1				
1229	147.49	.29	487		5.2			
1303	148.02	.53		6.8	5.0			1
1100	170.00	21.98						10
1129	170.48	.48						11
1144	170.73	.25	493	8.4				
1201	171.02	.29	500		5.5			12
1224	171.40	.38	509	7.8				
1244	171.73	.33	517		5.5			
1301	172.02	.29	524	7.7				
1318	172.32	.30	531		5.5			
1338	172.65	.33	539	7.6				
1358	172.98	.33	547		5.6			
1418	173.32	.34	555	7.8				
1443	173.73	.41	565		5.6			
1510	174.19	.46	576	7.8				
1538	174.65	.46	587		5.7			
1603	175.06	.41	597	8.1				
1629	175.48	.42	607		5.7			
1631	175.51	.03		7.6	5.5			1

NOTES:
1. 2200 RPM, 180 Nm.
2. 2100 RPM, 100% Torque
3. July 18.
4. Adjust time for decimal rounding.
5. July 19.
6. Probably 15 minutes unrecorded running time.
7. July 20.
8. Warmup.
9. Particulate and gaseous emissions, cycles 430-487.
10. July 24.
11. Time approximate.
12. Samples for Ames and sulphates, cycles 500-607.

Table 13

TRANSIENT CYCLE

POT Type II Fuel Diesel 20% Additive 90mg/L Cerium

Test Date Aug. 13, 14, 15, 19, 1985

TIME clock	hours elapsed	hours diff'l	CYCLES	BACKPRESSURE DP - kPa left	BACKPRESSURE DP - kPa right	TEMPERATURES Deg C average left	TEMPERATURES Deg C average right	NOTE
1500	.00	.00						
1532	.53	.53						
1538	.63	.10		2.6	2.2			1
1553	.88	.25		2.7	2.4			
1600	1.00	.12	0					
1607	1.12	.12	3	2.6				
1620	1.33	.21	18		2.3			
1632	1.54	.21		3.0				
1645	1.75	.21			2.5			
1650	1.83	.08		3.2	2.8			2
1654	1.90	.07		3.2	2.6			
1000	19.00	17.10						3
1045	19.75	.75						
1052	19.87	.12	21		2.9			
1102	20.04	.17	25	3.8				
1117	20.29	.25	31		3.0			
1132	20.54	.25	37	4.1		438		
1147	20.79	.25	43		3.0	437		
1202	21.04	.25	49	4.3		436		
1217	21.29	.25	55		3.2	434		
1232	21.54	.25	61	4.6			461	
1247	21.79	.25	67		3.2		462	
1302	22.04	.25	73	4.7			463	
1317	22.29	.25	79		3.2		466	
1332	22.54	.25	85	4.8			465	
1347	22.79	.25	91		3.2			
1402	23.04	.25	97	5.0				4
1417	23.29	.25	103		3.3			
1432	23.54	.25	109	5.0				
1447	23.79	.25	115		3.3			
1502	24.04	.25	121	5.1				
1517	24.29	.25	127		3.4			
1532	24.54	.25	133	5.4				
1547	24.79	.25	139		3.4			
1602	25.04	.25	145	5.5				
1615	25.25	.21	150		3.4			
1619	25.32	.07		5.4	3.6			2
1621	25.35	.03		5.4	3.4			
1623	25.38	.03		5.5	3.4			
1100	44.00	18.62						5
1140	44.67	.67						
1152	44.88	.21	155	6.5			450	
1207	45.13	.25	161		3.8		449	
1222	45.38	.25	167	6.6			444	
1237	45.63	.25	173		4.0		450	
1252	45.88	.25	179	6.8		428		

TIME clock	hours elapsed	hours diff'l	CYCLES	BACKPRESSURE DP - kPa left	BACKPRESSURE DP - kPa right	TEMPERATURES Deg C average left	TEMPERATURES Deg C average right	NOTE
1315	46.26	.38	188		4.1			
1332	46.55	.29	195	7.1				6
1405	47.09	.54	208		4.1			
1440	47.67	.58	222	7.5				
1517	48.29	.62	237		4.3			
1553	48.87	.58	251	8.1				
1620	49.32	.45		7.9	4.4			2
1622	49.35	.03		8.0	4.3			
1230	141.50	92.15						7
1241	141.68	.18		7.7	3.9			2
1243	141.71	.03		8.1	4.3			
1245	141.74	.03		9.2	4.9			1
1247	141.77	.03		7.3	4.5			
1249	141.80	.03		6.2				
1249	141.91	.01		5.1	3.4			2
1251	141.84	.03		4.7	3.1			
1300	142.00	.16				431		
1322	142.38	.38	260	5.9		435		
1335	142.59	.21	265		3.7	433		
1350	142.84	.25	271	6.9		438		
1405	143.09	.25	277		3.9	435		
1420	143.34	.25	283	7.3				
1440	143.67	.33	291		4.1			
1500	144.00	.33	299	7.7				8
1535	144.58	.58	313		4.2			
1615	145.25	.67	329	8.0				
1652	145.87	.62	344		4.4			
1654	145.90	.03		8.4	4.5			2
1656	145.93	.03		8.4	4.3			

NOTES
1. 2100 RPM, 100% torque
2. 2200 RPM, 181 Nm
3. August 14
4. Particulate samples
5. August 15, .3h warmup
6. Ames and metal samples
7. August 19
8. Ames and sulphate samples

ORE

TABLE 25

Engine Baseline - MTU Mod 5 Cycle - Diesel 20X

29-Aug-85 FILE : PART

New Diesel 1: Mar-85

Transient Particulate Emission Data Sheet

Filter #	1	2	3	4	5	6
Cycle						
rpm	2088	2088	2088			
Torque (N-m)	449.0	449.0	449.0			
FW	98.2	98.2	98.2	0.0	0.0	0.0
Fuel (gr/s)	7.65	7.65	7.65			
Pri Tunnel Flow(m3/min)	50.0	50.0	50.0			
Dilution Ratio	4.90	4.90	4.90			
(gr/hr)						
InSoluble	55.64	59.53	60.80	ERR	ERR	ERR
Soluble	12.75	14.01	8.81	ERR	ERR	ERR
Total	68.39	73.53	69.61	ERR	ERR	ERR
(gr/Kw-hr)						
InSoluble	0.567	0.606	0.619	ERR	ERR	ERR
Soluble	0.130	0.143	0.090	ERR	ERR	ERR
Total	0.697	0.749	0.709	ERR	ERR	ERR
(gr/Kgfuel)						
InSoluble	2.020	2.161	2.208	ERR	ERR	ERR
Soluble	0.463	0.509	0.320	ERR	ERR	ERR
Total	2.483	2.670	2.528	ERR	ERR	ERR
(mg/m**3)						
InSoluble	90.88	97.23	99.31	ERR	ERR	ERR
Soluble	20.83	22.88	14.39	ERR	ERR	ERR
Total	111.71	120.10	113.70	ERR	ERR	ERR
%						
InSoluble	81.4	81.0	87.3	ERR	ERR	ERR
Soluble	18.6	19.0	12.7	ERR	ERR	ERR

ORE

TABLE 26

31-Jul-85 FILE : PART - Type II PCTs - MTU MOD 5 Cycle
- Diesel 20%

Name Please Transient Particulate Emission Data Sheet Page 1
16-May-85

Filter #	1	2	3	4	5	6
Cycle rpm	2110	2110	2110	2110	2110	
Torque (N-m)	443.0	443.0	443.0	444	444	
KW	97.9	97.9	97.9	98.1	98.1	0.0
Fuel (gr/s)	7.69	7.69	7.69	7.67	7.67	
Pri Tunnel Flow(m3/min)	50.3	50.3	50.3	50.3	50.3	
Dilution Ratio	4.68	4.68	4.68	4.68	4.68	
(gr/hr) .						
InSoluble	23.81	24.22	23.25	43.02	24.64	ERR
Soluble	2.60	1.76	1.32	3.07	2.20	ERR
Total	26.40	25.98	24.56	46.10	26.83	ERR
(gr/Kw-hr)						
InSoluble	0.243	0.247	0.238	0.439	0.251	ERR
Soluble	0.027	0.018	0.013	0.031	0.022	ERR
Total	0.270	0.265	0.251	0.470	0.274	ERR
(gr/Kgfuel)						
InSoluble	0.860	0.875	0.840	1.558	0.892	ERR
Soluble	0.094	0.064	0.048	0.111	0.080	ERR
Total	0.954	0.938	0.887	1.669	0.972	ERR
(mg/m**3)						
InSoluble	36.91	37.55	36.05	66.72	38.20	ERR
Soluble	4.03	2.73	2.04	4.77	3.41	ERR
Total	40.94	40.28	38.09	71.48	41.61	ERR
%						
InSoluble	90.2	93.2	94.6	93.3	91.8	ERR
Soluble	9.8	6.8	5.4	6.7	8.2	ERR

?

ORF

TABLE 27 Type II PCTs - MTU MOD 5 Cycle
- Diesel 70% + 90 wy Cetane /L

20-Aug-85 FILE : PART

Name Please
16-May-85

Transient Particulate Emission Data Sheet

Filter #	1	2	3	4	5	6
Cycle						
rpm	2058	2058	2058	0	0	
Torque (N-m)	445.0	445.0	445.0	0	0	
KW	95.9	95.9	95.9	0.0	0.0	0.0
Fuel (gr/s)	7.49	7.49	7.49	0.00	0.00	
Pri Tunnel Flow(m3/min)	49.7	49.7	49.7	0.0	0.0	
Dilution Ratio	5.17	5.17	5.17	0	0	
(gr/hr)						
InSoluble	13.64	17.00	15.99	ERR	ERR	ERR
Soluble	3.52	2.62	2.43	ERR	ERR	ERR
Total	17.16	19.62	18.42	ERR	ERR	ERR
(gr/Kw-hr)						
InSoluble	0.142	0.177	0.167	ERR	ERR	ERR
Soluble	0.037	0.027	0.025	ERR	ERR	ERR
Total	0.179	0.205	0.192	ERR	ERR	ERR
(gr/Kgfuel)						
InSoluble	0.506	0.631	0.593	ERR	ERR	ERR
Soluble	0.131	0.097	0.090	ERR	ERR	ERR
Total	0.636	0.728	0.683	ERR	ERR	ERR
(mg/m**3)						
InSoluble	23.62	29.48	27.72	ERR	ERR	ERR
Soluble	6.10	4.53	4.22	ERR	ERR	ERR
Total	29.72	34.01	31.94	ERR	ERR	ERR
%						
InSoluble	79.5	86.7	86.8	ERR	ERR	ERR
Soluble	20.5	13.3	13.2	ERR	ERR	ERR

TABLE 28

25-Jul-85 FILE : SULF

Type II Test - MTU MOD 5 Cycle
- Diesel 20%

Name Please Transient Sulphate Emission Data Sheet Page 3
30-May-85

Test #	1	2	3	4	5	6
Cycle						
rpm	2108	2108	2108			
Torque (N-m)	443.0	443.0	443.0			
FW	97.8	97.8	97.8	0.0	0.0	0.0
Fuel (gr/s)	7.70	7.70	7.70			
Sulphur (%)	0.31	0.31	0.31			
Engine Exhaust Flow(m3/min)	10.60	10.60	10.60			
Dilution Ratio	4.800	4.800	4.800			
Concentration in raw exhaust						
SO2(ppm)	97.01	80.75	103.08	ERR	ERR	ERR
SO4(ppm)	0.00	0.00	0.00	ERR	ERR	ERR
Total(ppm)	97.01	80.75	103.08	ERR	ERR	ERR
SO2 (mg/m**3)	258.41	215.12	274.60	ERR	ERR	ERR
SO4 (mg/m**3)	0.00	0.00	0.00	ERR	ERR	ERR
Emission Rate						
SO2 (gr/hr)	164.35	136.82	174.65	ERR	ERR	ERR
SO4 (gr/hr)	0.00	0.00	0.00	ERR	ERR	ERR
SO2 (gr/Kw-hr)	1.68	1.40	1.79	ERR	ERR	ERR
SO4 (gr/Kw-hr)	0.00	0.00	0.00	ERR	ERR	ERR
SO2 (g/KgFuel)	5.93	4.94	6.30	ERR	ERR	ERR
SO4 (g/KgFuel)	0.00	0.00	0.00	ERR	ERR	ERR
Theoretical SO2 Calculation (ppm)	101.69	101.69	101.69	ERR	ERR	ERR

Eliminate data

ORF

TABLE 29

Type II POTs - MTH Cycle
- Diesel 20%
+ 91 by Cetane 1L

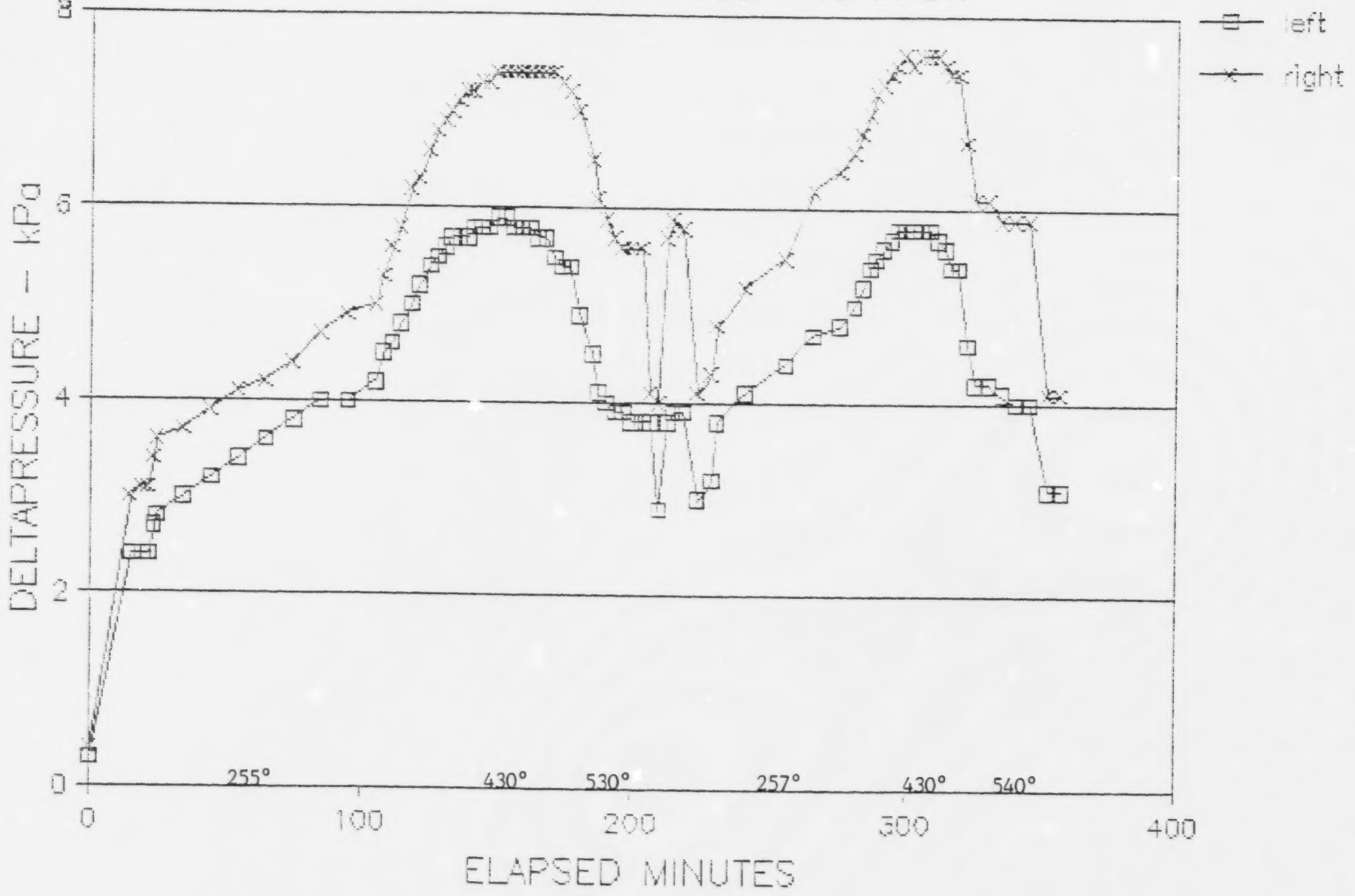
21-MAY-85 FILE : SULF

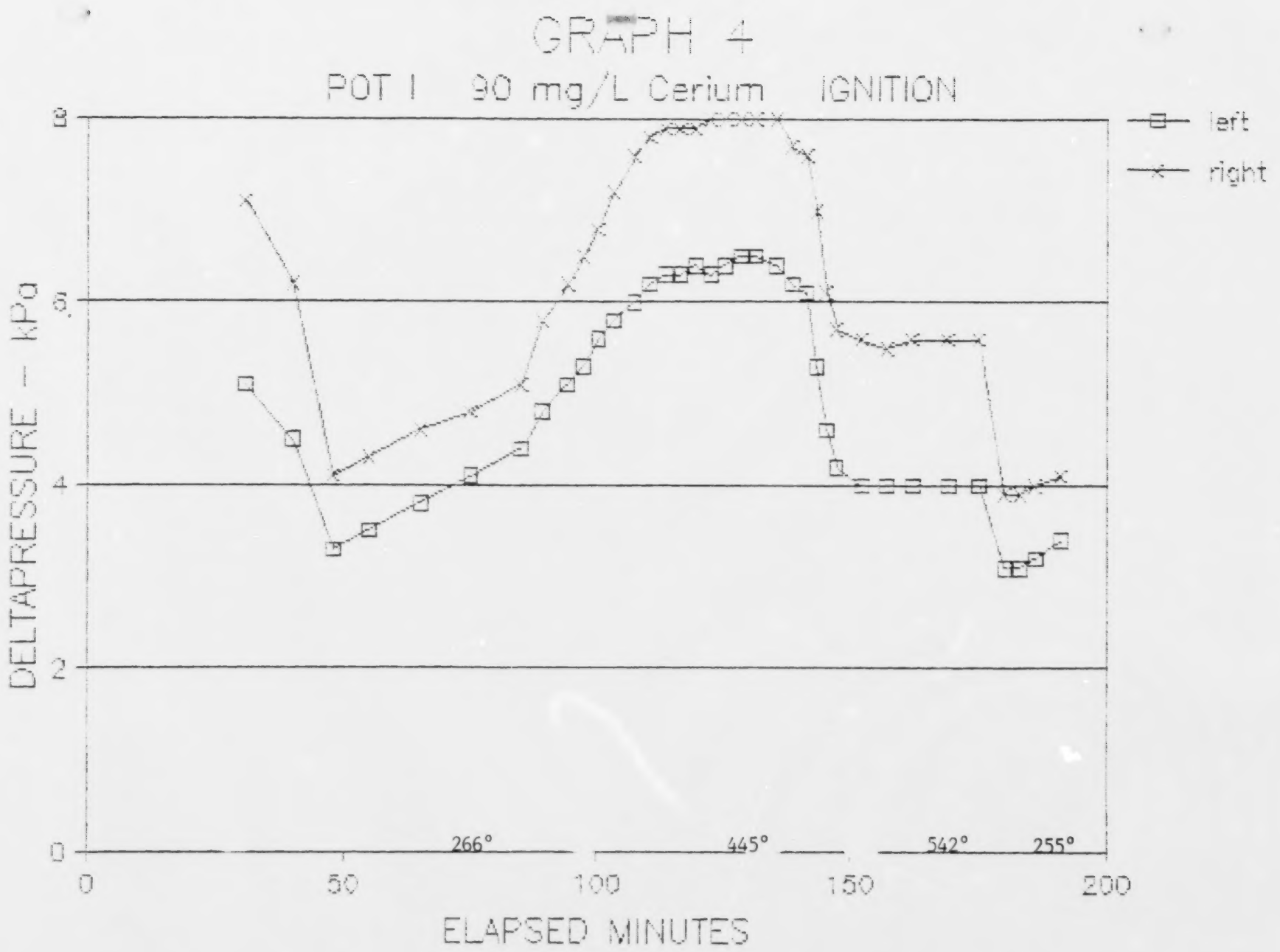
Ford Fiesta — Transient Sulphate Emission Data Sheet — Page 7
2-Dec.-85

Test #	1	2	3	4	5	6
Cycle						
rpm	2071	2071	2071			
Torque (N-m)	445.0	445.0	445.0			
kW	96.5	96.5	96.5	0.0	0.0	0.0
Fuel (gr/s)	7.54	7.54	7.54			
Sulphur (%)	0.31	0.31	0.31			
Engine Exhaust Flow(m3/min)	9.81	9.81	9.81			
Dilution Ratio	5.100	5.100	5.100			
Concentration in raw exhaust						
SO2(ppm)	112.54	120.44	118.14 $\bar{x}$ 117.04	ERR	ERR	ERR
SO4(ppm)	2.62	0.75	1.68 $\bar{x}$ 1.66	ERR	ERR	ERR
Total(ppm)	115.16	121.19	119.82	ERR	ERR	ERR
SO2 (mg/m**3)	299.79	320.84	314.70	ERR	ERR	ERR
SO4 (mg/m**3)	10.47	3.00	6.73	ERR	ERR	ERR
Emission Rate						
SO2 (gr/hr)	176.45	188.85	185.23	ERR	ERR	ERR
SO4 (gr/hr)	6.16	1.77	3.96	ERR	ERR	ERR
SO2 (gr/Kw-hr)	1.83	1.96	1.92	ERR	ERR	ERR
SO4 (gr/Kw-hr)	0.06	0.02	0.04	ERR	ERR	ERR
SO2 (g/KgFuel)	6.50	6.96	6.82	ERR	ERR	ERR
SO4 (g/KgFuel)	0.23	0.07	0.15	ERR	ERR	ERR
Theoretical SO2 Calculation (ppm)	107.60	107.60	107.60	ERR	ERR	ERR

GRAPH 3

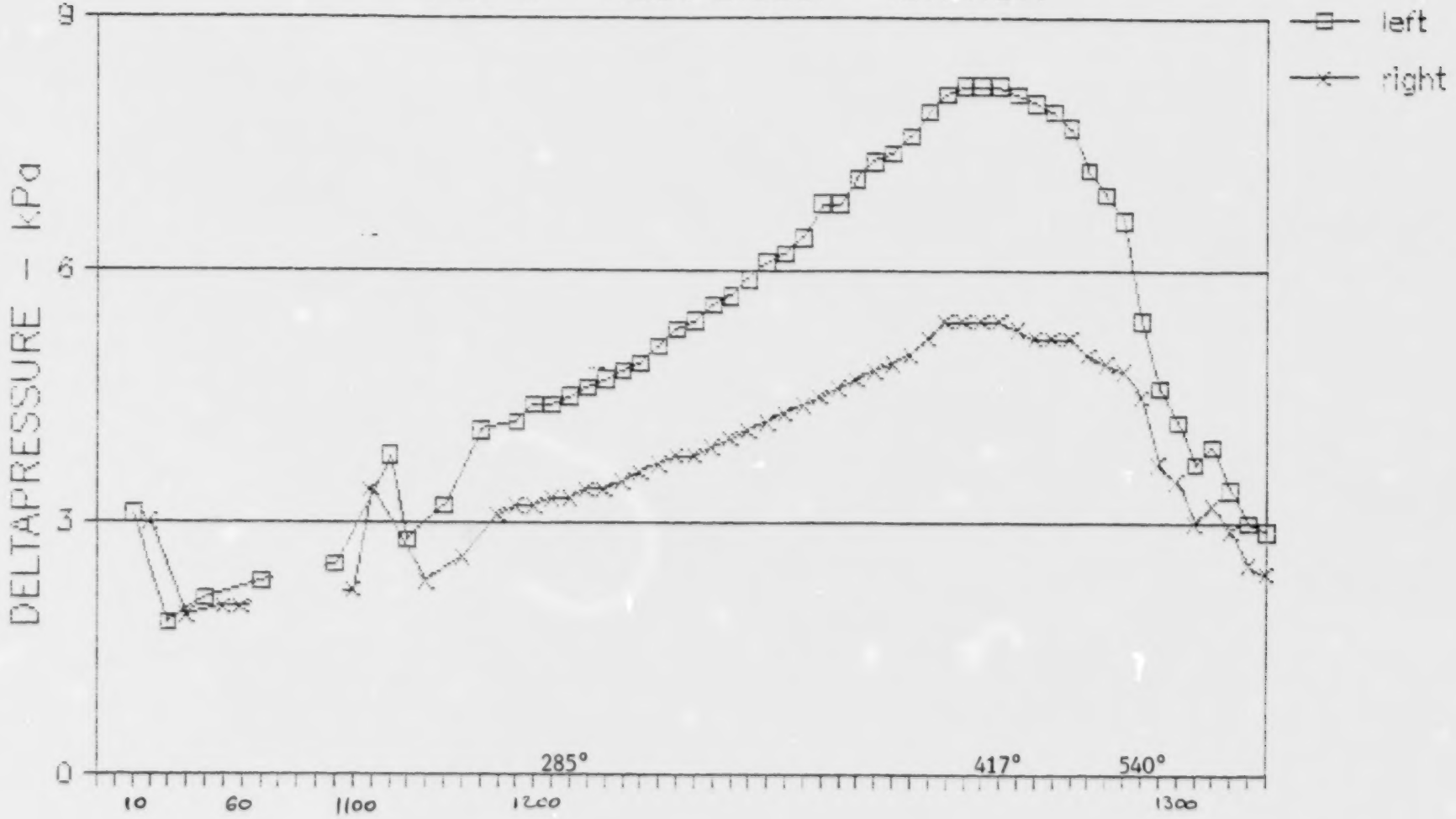
POT 1 Neat Diesel IGNITION



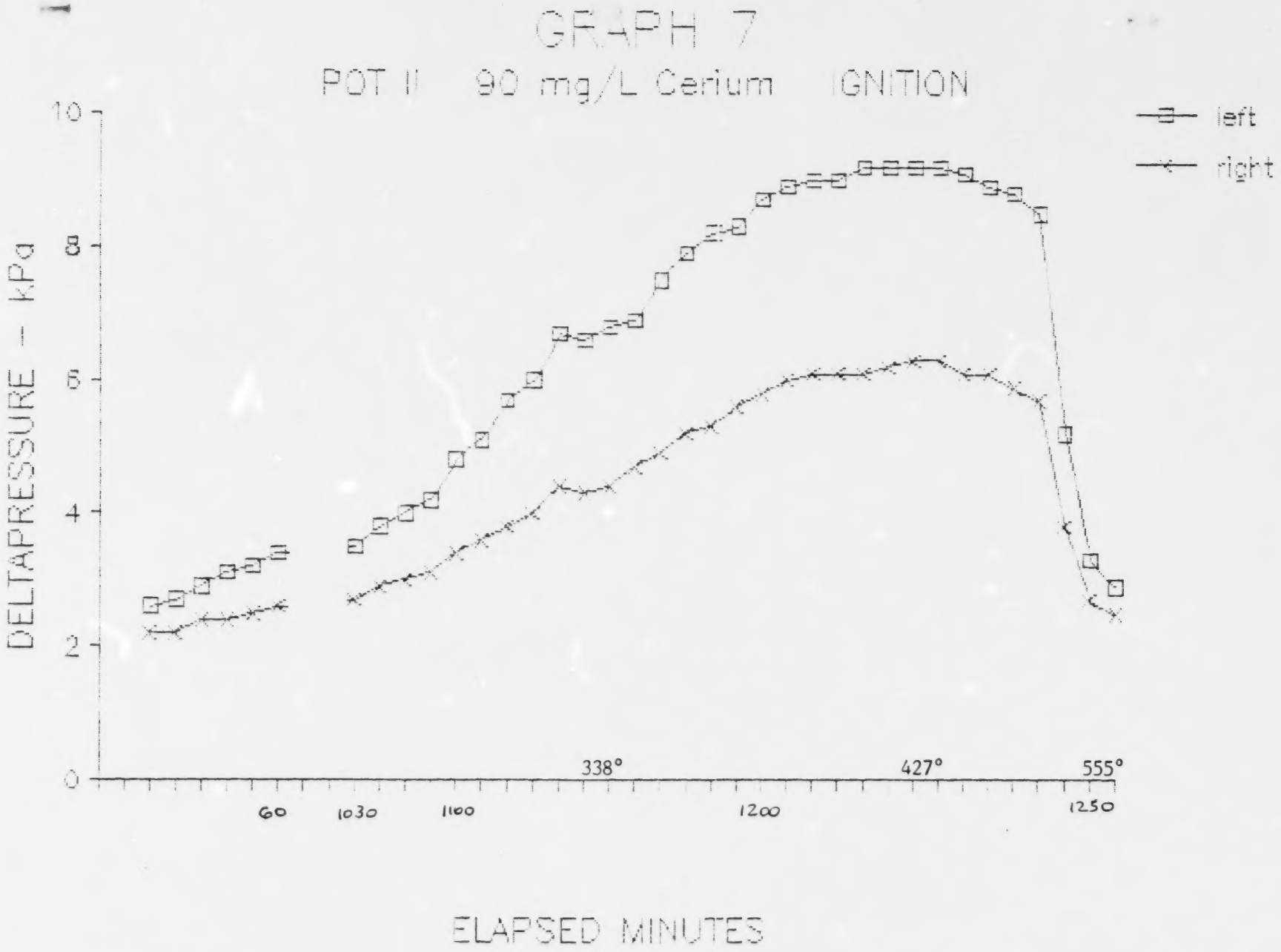

GRAPH 4
POT I 90 mg/L Cerium IGNITION
left
right
DELTAPRESSURE - kPa
0
2
4
6
8
266°
445°
542°
255°
0
50
100
150
200
ELAPSED MINUTES

GRAPH 5

POT II Neat Diesel IGNITION

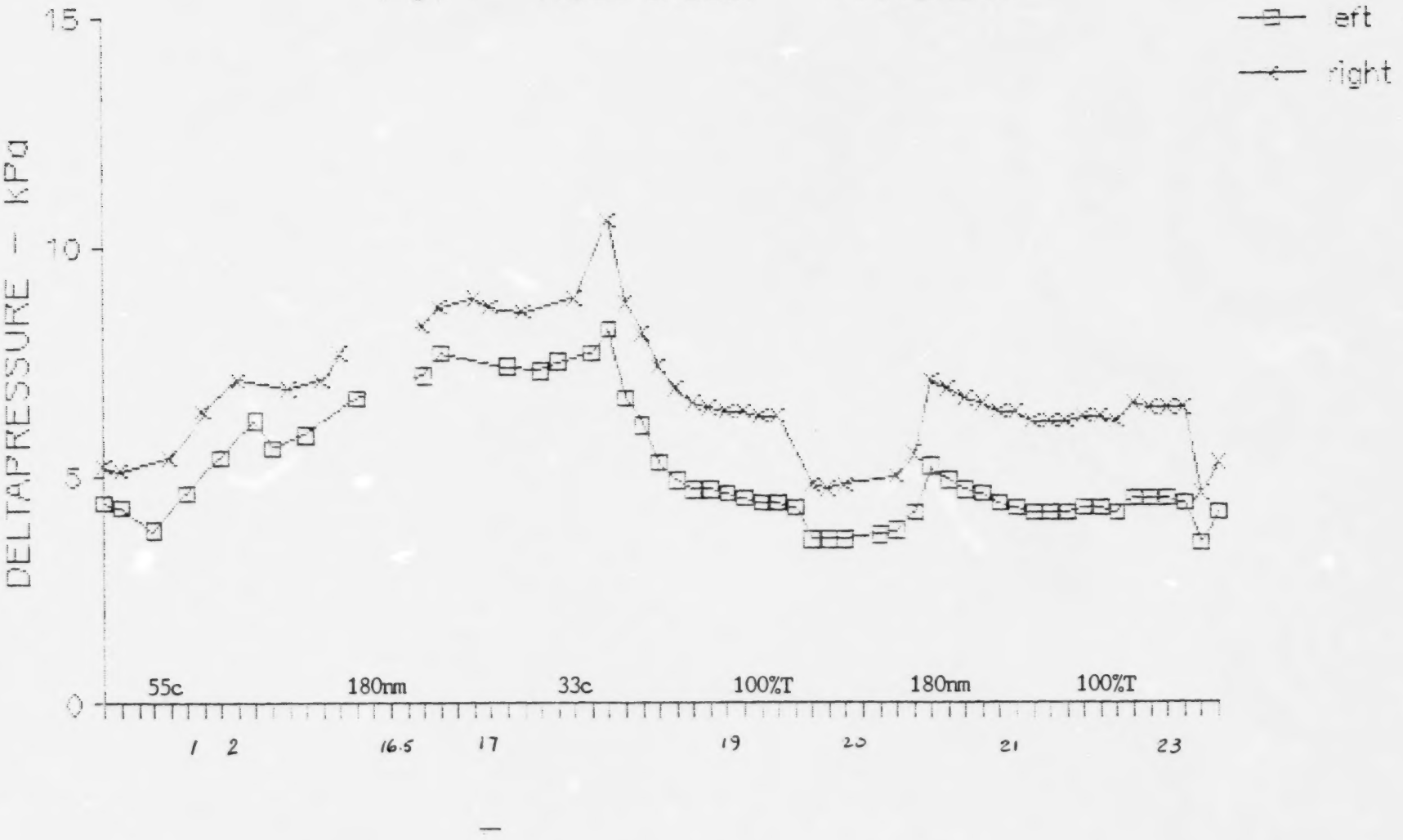


ELAPSED MINUTES


GRAPH 7
POT II 90 mg/L Cerium IGNITION
left
right
DELTAPRESSURE - kPa
0
2
4
6
8
10
338°
427°
555°
60
1030
1100
1200
1250
ELAPSED MINUTES

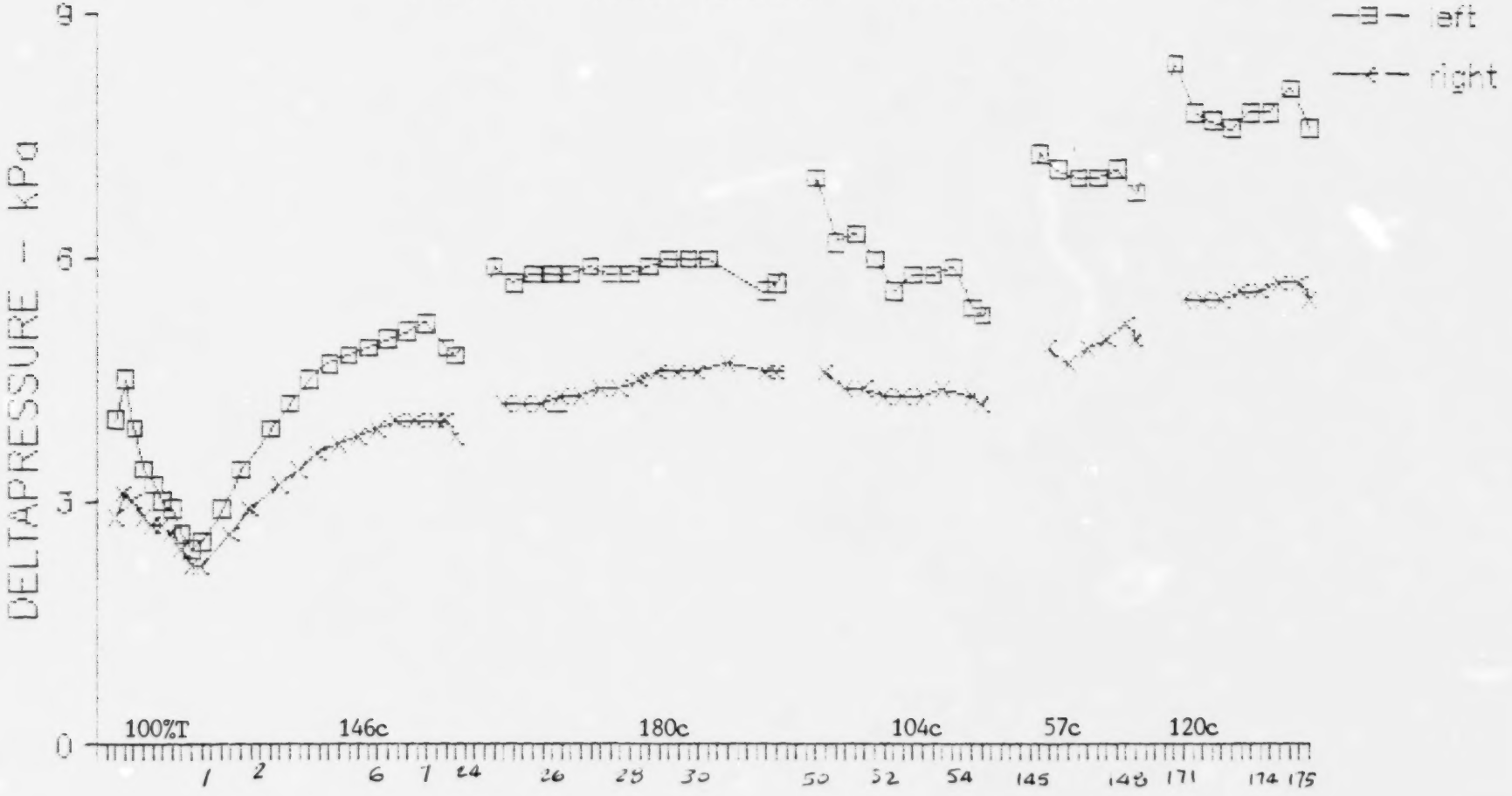
GRAPH 11

POT 1 Neat Diesel TRANSIENT



GRAPH 12

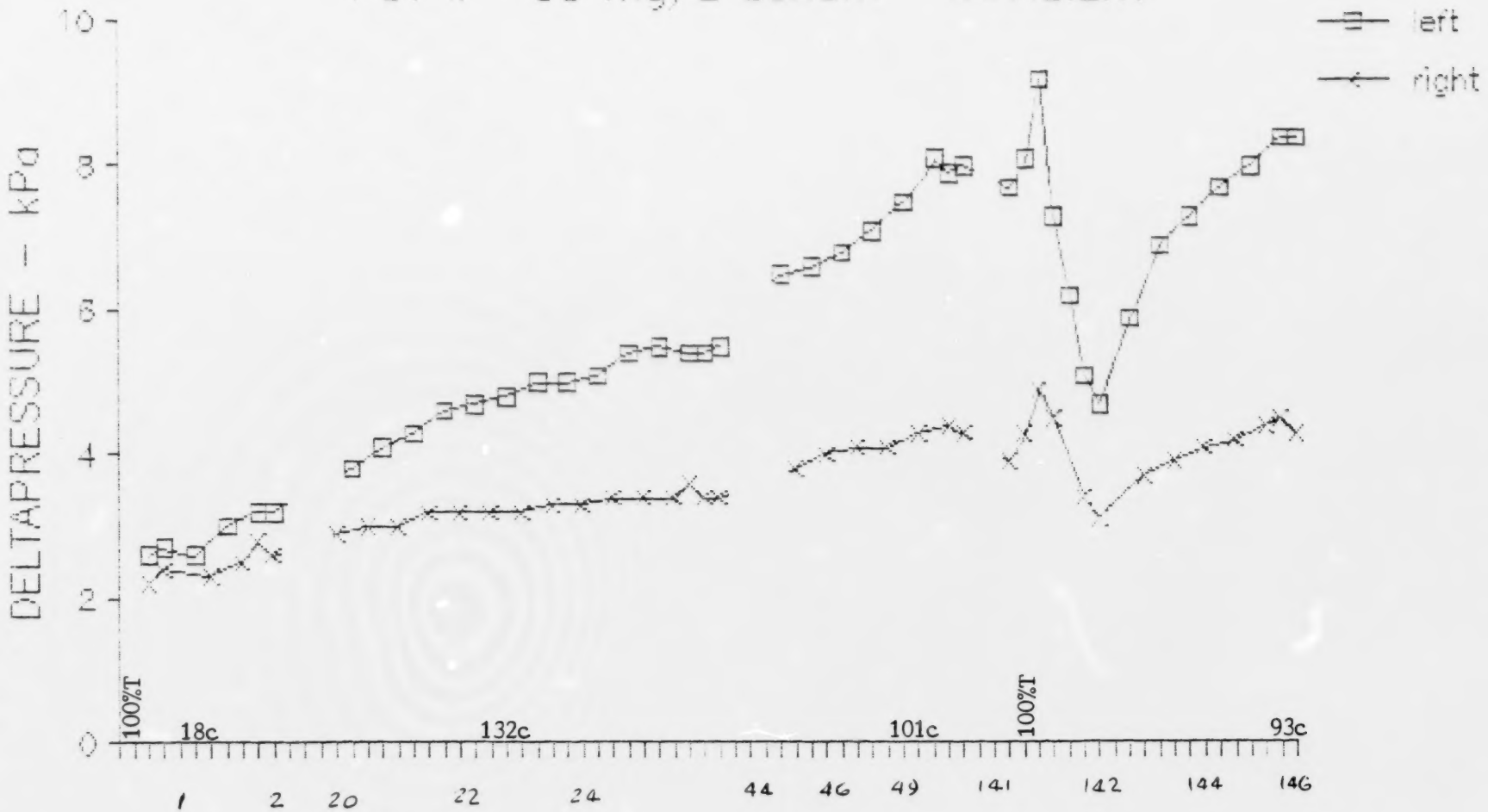
POT II Neat Diesel TRANSIENT



ELAPSED HOURS

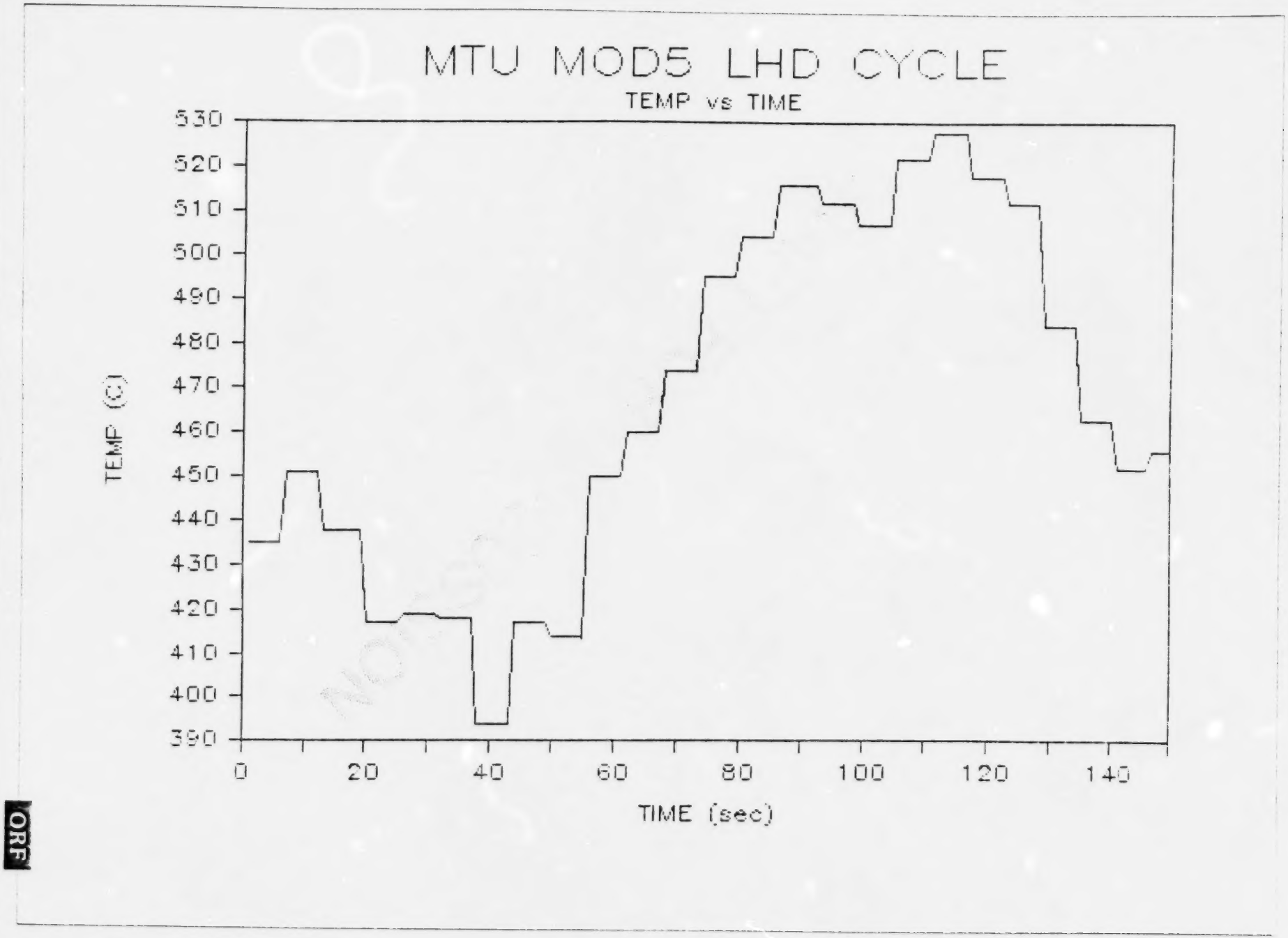
GRAPH 13

POT II 30 mg/L Cerium TRANSIENT

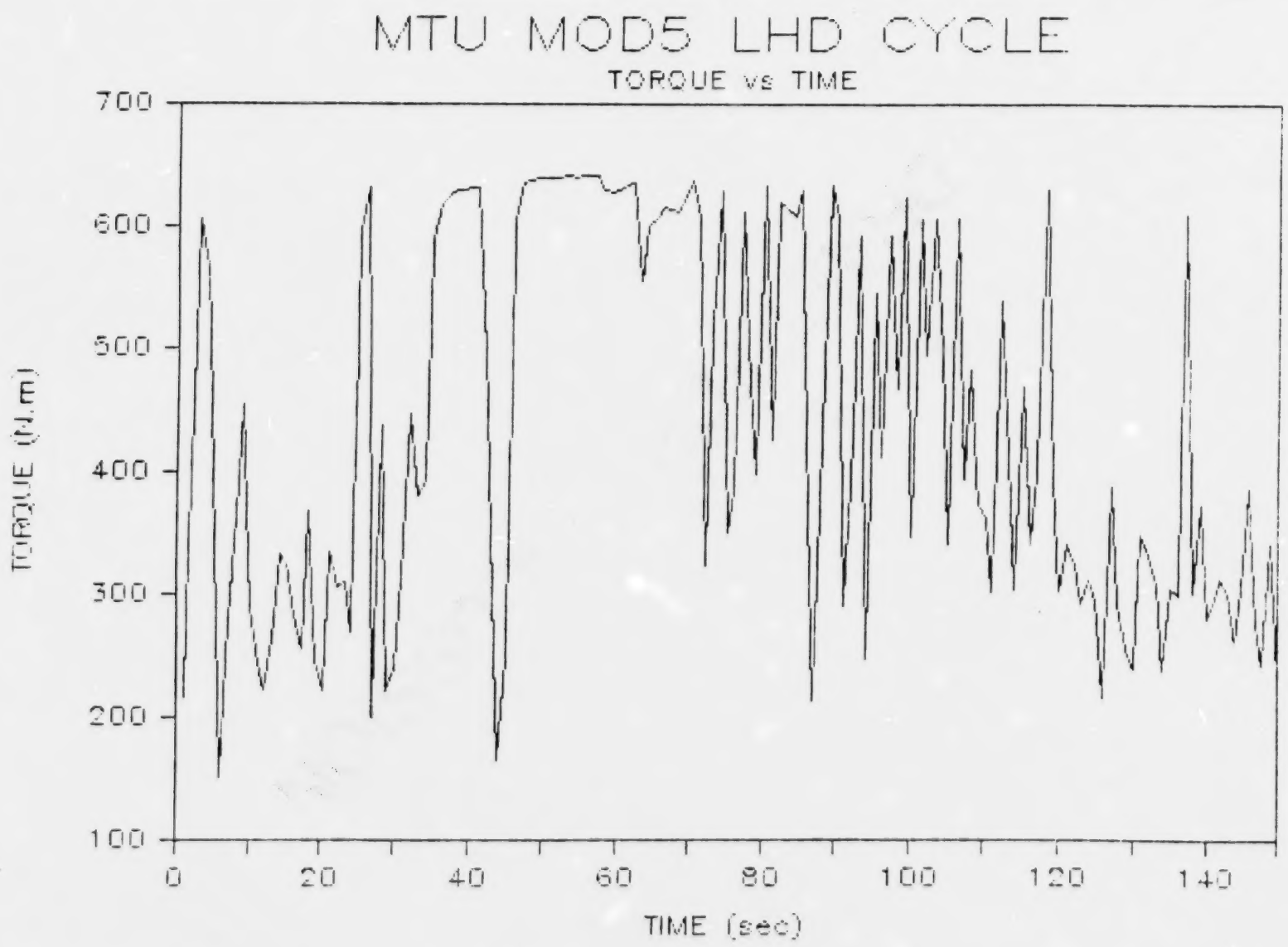


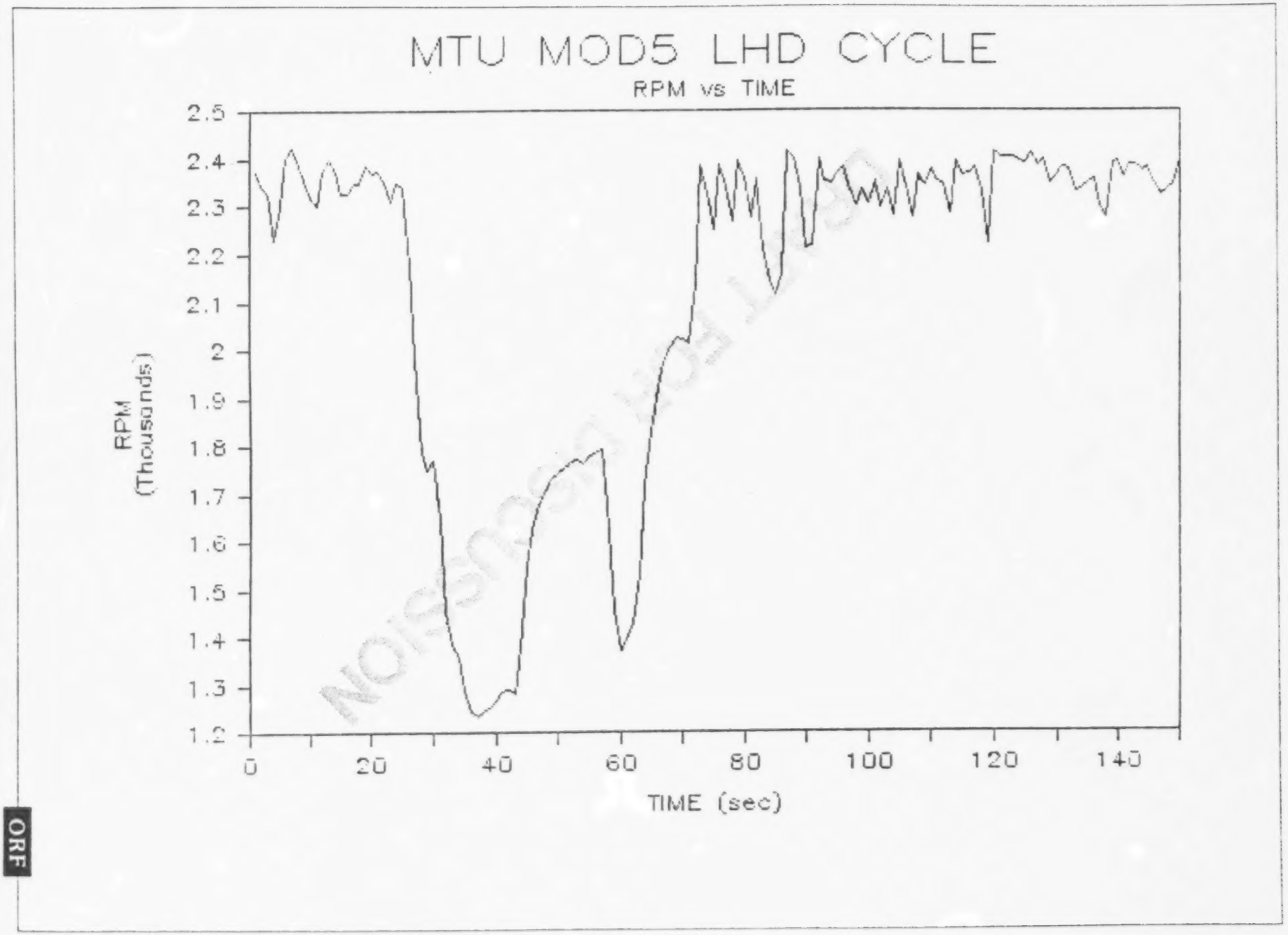
ELAPSED HOURS

APPENDIX


MTU MOD5 LHD CYCLE
TEMP vs TIME
TEMP (C)
530
520
510
500
490
480
470
460
450
440
430
420
410
400
390
0
20
40
60
80
100
120
140
TIME (sec)

ORF


MTU MOD5 LHD CYCLE
TORQUE vs TIME
700
600
500
400
300
200
100
TORQUE (N.m)
0
20
40
60
80
100
120
140
TIME (sec)



NOT FOR USE
ORF

ORF

ANALYSIS OF CERIUM PASSTHROUGH

BASELINE

SAMPLE	TOTAL CERIUM MG	SAMPLE VOL (M**3)	DILUTION RATIO	CONCENTRATION (MG/M**3)
#8	338	0.4678	4.95	3.57
#9	274	0.5438	4.95	2.49
#10	305	0.4768	4.95	3.17
AVERAGE				3.08
THEORETICAL (FROM FUEL ANALYSIS)				4.84

PERCENT CERIUM RECOVERY = 63.6%

TO PASSTHROUGH

SAMPLE	TOTAL CERIUM MG	SAMPLE VOL (M**3)	DILUTION RATIO	CONCENTRATION (MG/M**3)
#3	115	0.8298	4.95	0.685
#4	132	0.802	4.95	0.816
#5	110	0.8429	4.98	0.649
AVERAGE				0.717
THEORETICAL (FROM FUEL ANALYSIS)				4.93

PERCENT CERIUM PASSTHROUGH 14.5%
(BASED ON TOTAL FUEL CERIUM)

PERCENT CERIUM PASSTHROUGH 23.3%
(BASED ON EXHAUST CERIUM)

TOTAL CERIUM USED DURING TESTS = 31326 MG
TOTAL CERIUM IN LUBE OIL = 919 MG

ORF

MEM.

September 12, 1985

To : Brian Manicom
From : Art Horton

Subject : Ames testing of supplied particulate samples
Work Order # F21240

Three sets of eight (8x10) HI-VOL filter samples were supplied for Ames Salmonella mutagenicity testing. The samples were identified as :

1. ECS Baseline
2. ECS Type II CTO's - Neat Diesel
3. Ecs Type II CTO's - Cerium fuel additive

The samples were Soxhlet extracted for 16 hours with dichloromethane and the soluble organic fraction (SOF) was determined.

		Mg per cubic meter			
1.	Baseline	TPM	92.7	SOF	13.5
2.	CTO	TPM	36.8	SOF	5.8
3.	CTO+additive	TPM	22.0	SOF	2.9

Both the CTO and CTO plus fuel additive showed a reduction in total particulate material (TPM) and SOF under the conditions tested.

Ames Test Results

The SOF obtained for each sample was dissolved in DMSO at a concentration of 10 Mg/mL (10,000 ug /mL).The samples were tested with Salmonella tester strain TA-98 without metabolic activation over a concentration range of 10 to 600 ug per plate.

The Ames test results for the three samples are presented in tables 1 to 3 along with the positive and negative control data. The controls indicate the assay system was functioning properly.

The ECS Baseline sample was positive and mutagenic for Salmonella tester strain TA-98 without metabolic activation. The specific activity was 2.9 revertants per ug. This translates to a mutagen concentration of 39,150 revertants per cubic meter.

Both the CTO- neat diesel and the CTO plus fuel additive samples were negative and non mutagenic for Salmonella tester strain TA-98 without metabolic activation.

A. J. Horton

ORF

TABLE : 1

ECS Baseline
Salmonella Tester Strain TA-98

	CONCENTRATION ug / PLATE	S-9 MIX	HISTIDINE REVERTANTS			MEAN	STD +/-	NET. REV.
	600	-	950	959	835	915	69	875
	400	-	697	577	724	666	78	626
	300	-	490	564	438	497	63	457
	250	-	542	759	846	716	157	676
	200	-	372	486	524	461	79	421
*	150	-	436	480	575	497	71	457
*	100	-	391	472	391	418	47	378
*	50	-	302	286	301	296	9	256
*	25	-	148	144	159	150	8	110
*	10	-	101	96	86	94	8	54
	NEGATIVE CONTROL	-	30	52	41	35 40	40	8
	HISTORICAL VALUE	-					31	
	POSITIVE CONTROL	-		492	490	481	488	6
	HISTORICAL VALUE	-					619	
	COMPOUND		2 Nitrofluorene			2 ug / plate		
	MUTAR						28	
	SPECIFIC ACTIVITY						2.9	

* point used to calculate specific activity

TABLE : 2

ECS Type II CTO s -Neat Diesel
Salmonella Tester Strain TA-98

CONCENTRATION ug / PLATE	S-9 MIX	HISTIDINE REVERTANTS			MEAN	STD +/-	NET. REV.
600	-	53	60	84	66	17	26
400	-	47	53	52	51	3	11
300	-	64	62	74	67	6	27
250	-	75	59	70	68	8	28
200	-	52	53	44	50	5	10
150	-	61	50	66	59	8	19
100	-	54	60	63	59	5	19
50	-	46	46	37	43	5	3
25	-	36	35	34	35	1	-
10	-	40	46	39	42	4	2
NEGATIVE CONTROL	-	30	52	41	35	40	40	8	
HISTORICAL VALUE	-						31		
POSITIVE CONTROL	-		492		490	481	488	6	
HISTORICAL VALUE	-						619		
COMPOUND		2 Nitrofluorene 2 ug / plate							
MUTAR							0.9		
SPECIFIC ACTIVITY		Negative Non-Mutagenic							

TABLE : 3

ECS Type II CTO's -Cerium fuel additive
Salmonella Tester Strain TA-98

CONCENTRATION ug / PLATE	S-9 MIX	HISTIDINE REVERTANTS			MEAN	STD +/-	NET. REV.
600	-	106	79	101	95	14	55
400	-	65	67	48	60	10	20
300	-	68	53	92	71	20	31
250	-	70	61	71	67	6	27
200	-	60	71	79	70	10	30
150	-	67	53	74	65	11	25
100	-	63	63	37	54	15	14
50	-	48	50	55	51	4	11
25	-	40	53	53	49	8	9
10	-	47	40	54	47	7	7
NEGATIVE CONTROL	-	30	52	41	35	40	40	8	
HISTORICAL VALUE	-						31		
POSITIVE CONTROL	-		492		490	481	488	6	
HISTORICAL VALUE	-						619		
COMPOUND		2 Nitrofluorene 2 ug / plate							
MUTAR							1.8		
SPECIFIC ACTIVITY		Negative Non-Mutagenic							

QUALITY

ORF

04-Oct-85 FILE: PDT2SP

Table 111
Particulate + Sulphur-Emission
PDT Type 11
MIU-LHD Cycle (Mod 5)

	BASELINE	Neat Diesel	Neat Diesel +90 mg Ce/Diesel
Particulate			
Insoluble			
(mg/m**3)	95.8	37.2	26.9
(% Total)	83.2%	92.4%	84.5%
Soluble			
(mg/m**3)	19.4	3.1	5.0
(% Total)	16.8%	7.6%	15.5%
Total			
(mg/m**3)	115.2	40.2	31.9
SO2 (mg/m**3)		266.5	311.8
SO4 (mg/m**3)		0.0	6.7
TOTAL SULPHUR (ppm)		100.4 (101.7)	118.7 (107.6)

( )- total sulphur from fuel

04-Oct-85 FILE : PDT2BASE

Gaseous Emission Summary
Baseline
MTU-LHD MOD 5

	PPM	g/hr	g/kwh	g/kg fuel
CO	237	169	1.72	6.12
THC	122	50.0	0.51	1.81
NO	486	371	3.77	13.5
NO2	14	16.3	0.166	0.59
NOX (as NO2)	500	587	5.99	21.2

04-Oct-85 FILE : PDT2NEAT

Gaseous Emission Summary
PDT II + 90 mg Ce/L diesel
MTU-LHD MOD 5

	PPM	g/hr	g/kwh	g/kg fuel
CO	234	172	1.75	6.21
THC	74	31.4	0.32	1.13
NO	445	344	3.5	12.5
NO2	16	18.9	0.193	0.69
NOX (as NO2)	461	571	5.84	20.7

04-Oct-85 FILE : PDT2CER

Gaseous Emission Summary
PDT II + 90 mg Ce/L diesel
MTU-LHD MOD 5

	PPM	g/hr	g/kwh	g/kg fuel
CO	262	176	1.82	6.52
THC	79.2	30.5	0.315	1.13
NO	446	322	3.31	11.9
NO2	18	20.1	0.206	0.738
NOX (as NO2)	464	512	5.31	19.0

(P)

ORF - EMISSION TEST FACILITY
SAMPLE DATA
TEST INITIALIZATION VALUES

[redacted]

Aug 27/85
MTU MOD 5
Gaseous
Baseline

REPORT REQUEST DATE:	08/27/85	
REPORT REQUEST TIME:	10:36:35	
TEST INITIALIZATION DATE:	08/27/85	
TEST INITIALIZATION TIME:	10:26:50	
AVERAGING OF DATA:	150 POINTS	
CELL NAME:	CL-5	
TEST ID:	ECS	
TEST NAME:	EMS 01	
TEST DESCRIPTION:	BASELINE	
ENGINE TYPE:		
ENGINE MODEL:		
ENGINE SERIAL NUMBER:		
ENGINE DISPLACEMENT:	12.800 LITRES	781.0 CU-IN
OPERATOR NAME:		
FUEL TYPE:		
GAS OR DIESEL :	DIESEL FUEL	
DIESEL ENGINE:	NATURALLY ASPIRATED 4 STROKES	
% CARBON IN FUEL:	85.900 PCT	
% HYDROGEN IN FUEL:	13.810 PCT	
BACKGROUND TOTAL HYDROCARBONS:	3.000 PPM	
AMBIENT DEWPOINT:	.0 DEG-C	32.0 DEG-F
AMBIENT VAPOR PRESSURE:	1.90 KPA	.56 IN-HG
ANALYZER DEWPOINT:	7.2 DEG-C	45.0 DEG-F
ANALYZER VAPOR PRESSURE	1.01 KPA	.30 IN-HG
BAROMETRIC PRESSURE:	102.1 KPA	30.2 IN-HG
AMBIENT CO2:	.032 PCT	
P.D. PUMP CALIBRATION FACTOR:	.0313 M3/MIN-REV	
RPM OF BLOWER:	1952.0 RPM	
DELAY TIME FOR ANALYZERS: 1 -	11 SEC	
2 -	21 SEC	
3 -	16 SEC	
4 -	34 SEC	
5 -	46 SEC	
6 -	23 SEC	
7 -	0 SEC	
8 -	0 SEC	

ORF - EMISSION TEST FACILITY
SAMPLE DATA

ENGINE TYPE: ENGINE MODEL: ENGINE SERIAL NUMBER:
OPERATOR NAME: FUEL TYPE: CELL NAME: CL-5

SAMPLE		75	0	0	0	0	0	0	0	0	0
STEP		75	0	0	0	0	0	0	0	0	0
ENGSP	RPM	2089.5	.0	.0	.0	.0	.0	.0	.0	.0	.0
ETORQ	N-M	445.4	.0	.0	.0	.0	.0	.0	.0	.0	.0
CTORQ	N-M	448.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
FULFA	G/S	7.72	.00	.00	.00	.00	.00	.00	.00	.00	.00
OBSFC	G/KWH	285.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
CBSFC	G/KWH	283.4	.0	.0	.0	.0	.0	.0	.0	.0	.0
EXHDP	KPA	2.481	.000	.000	.000	.000	.000	.000	.000	.000	.000
LINPO	MM	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
SMOKE	PCT	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
ECO2I	PCT	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
ECO2E	PCT	7.81	.00	.00	.00	.00	.00	.00	.00	.00	.00
E-THC	PPM	29.5	.0	.0	.0	.0	.0	.0	.0	.0	.0
E-CO	PPM	51.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
E-NO	PPM	99.7	.0	.0	.0	.0	.0	.0	.0	.0	.0
E-NOX	PPM	99.4	.0	.0	.0	.0	.0	.0	.0	.0	.0
EGR	PCT	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
QEW	M3/MIN	11.21	.00	.00	.00	.00	.00	.00	.00	.00	.00
QED	M3/MIN	10.24	.00	.00	.00	.00	.00	.00	.00	.00	.00
QTW	M3/MIN	51.8	.0	.0	.0	.0	.0	.0	.0	.0	.0
QTD	M3/MIN	50.1	.0	.0	.0	.0	.0	.0	.0	.0	.0
D.RATIO		4.9	.0	.0	.0	.0	.0	.0	.0	.0	.0
CO2	PCT	7.9	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	88291.9	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	900.6	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KG F	3178.6	.0	.0	.0	.0	.0	.0	.0	.0	.0
THC	PPM	136.6	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	56.1	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	.572	.000	.000	.000	.000	.000	.000	.000	.000	.000
	G/KG F	2.018	.000	.000	.000	.000	.000	.000	.000	.000	.000
CO	PPM	252.2	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	180.4	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	1.841	.000	.000	.000	.000	.000	.000	.000	.000	.000
	G/KG F	6.50	.00	.00	.00	.00	.00	.00	.00	.00	.00
NO	PPM	492.4	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	377.5	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	3.851	.000	.000	.000	.000	.000	.000	.000	.000	.000
	G/KG F	13.592	.000	.000	.000	.000	.000	.000	.000	.000	.000
NO2	PPM	10.1	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	11.9	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	.121	.000	.000	.000	.000	.000	.000	.000	.000	.000
	G/KG F	.428	.000	.000	.000	.000	.000	.000	.000	.000	.000
NOX(NO2)	PPM	502.5	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	590.8	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	6.026	.000	.000	.000	.000	.000	.000	.000	.000	.0
	G/KG F		000	.000	000	.000		000	000		

ORF - EMISSION TEST FACILITY
SAMPLE DATA

E[illegible] TYPE: ENGINE MODEL: ENGINE SERIAL NUMBER:
OPERATOR NAME: FUEL TYPE: CELL NAME: CL-5

SAMPLE		75	0	0	0	0	0	0	0	0	0
STEP		75	0	0	0	0	0	0	0	0	0
ENGSP	RPM	2089.1	.0	.0	.0	.0	.0	.0	.0	.0	.0
ETORQ	N-M	445.3	.0	.0	.0	.0	.0	.0	.0	.0	.0
CTORQ	N-M	448.1	.0	.0	.0	.0	.0	.0	.0	.0	.0
FULFA	G/S	7.69	.00	.00	.00	.00	.00	.00	.00	.00	.00
OBSFC	G/KWH	284.4	.0	.0	.0	.0	.0	.0	.0	.0	.0
CBSFC	G/KWH	282.7	.0	.0	.0	.0	.0	.0	.0	.0	.0
EXHDP	KPA	2.503	.000	.000	.000	.000	.000	.000	.000	.000	.000
LINPO	MM	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
SMOKE	PCT	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
ECO2I	PCT	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
ECO2E	PCT	7.80	.00	.00	.00	.00	.00	.00	.00	.00	.00
E-THC	PPM	25.9	.0	.0	.0	.0	.0	.0	.0	.0	.0
E-CO	PPM	47.3	.0	.0	.0	.0	.0	.0	.0	.0	.0
E-NO	PPM	98.6	.0	.0	.0	.0	.0	.0	.0	.0	.0
E-NOX	PPM	98.4	.0	.0	.0	.0	.0	.0	.0	.0	.0
EGR	PCT	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
QEW	M3/MIN	11.18	.00	.00	.00	.00	.00	.00	.00	.00	.00
QED	M3/MIN	10.22	.00	.00	.00	.00	.00	.00	.00	.00	.00
[illegible]	M3/MIN	51.7	.0	.0	.0	.0	.0	.0	.0	.0	.0
[illegible]	M3/MIN	50.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
D.RATIO		4.9	.0	.0	.0	.0	.0	.0	.0	.0	.0
CO2	PCT	7.8	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	88052.9	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	898.3	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KG F	3178.6	.0	.0	.0	.0	.0	.0	.0	.0	.0
THC	PPM	118.4	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	48.5	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	.495	.000	.000	.000	.000	.000	.000	.000	.000	.000
	G/KG F	1.751	.000	.000	.000	.000	.000	.000	.000	.000	.000
CO	PPM	233.8	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	167.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	1.703	.000	.000	.000	.000	.000	.000	.000	.000	.000
	G/KG F	6.03	.00	.00	.00	.00	.00	.00	.00	.00	.00
NO	PPM	487.1	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	372.7	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	3.802	.000	.000	.000	.000	.000	.000	.000	.000	.000
	G/KG F	13.453	.000	.000	.000	.000	.000	.000	.000	.000	.000
NO2	PPM	10.7	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	12.6	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	.128	.000	.000	.000	.000	.000	.000	.000	.000	.000
	G/KG F	.454	.000	.000	.000	.000	.000	.000	.000	.000	.000
NOX(NO2)	PPM	497.8	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	584.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	5.958	.000	.000	.000	.000	.000	.000	.000	.000	.000
	G/KG F	21.083	.000	.000	.000	.000	.000	.000	.000	.000	.000

SAMPLE DATA

ENGINE TYPE: ENGINE MODEL: ENGINE SERIAL NUMBER:
OPERATOR NAME: FUEL TYPE: CELL NAME: CL-5

SAMPLE		75	0	0	0	0	0	0	0	0	0
STEP		75	0	0	0	0	0	0	0	0	0
ENGSP	RPM	2091.7	.0	.0	.0	.0	.0	.0	.0	.0	.0
ETORQ	N-M	445.7	.0	.0	.0	.0	.0	.0	.0	.0	.0
CTORQ	N-M	448.7	.0	.0	.0	.0	.0	.0	.0	.0	.0
FULFA	G/S	7.67	.00	.00	.00	.00	.00	.00	.00	.00	.00
OBSFC	G/KWH	282.8	.0	.0	.0	.0	.0	.0	.0	.0	.0
CBSFC	G/KWH	280.9	.0	.0	.0	.0	.0	.0	.0	.0	.0
EXHDP	KPA	2.515	.000	.000	.000	.000	.000	.000	.000	.000	.000
LINPO	MM	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
SMOKE	PCT	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
ECO2I	PCT	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
ECO2E	PCT	7.79	.00	.00	.00	.00	.00	.00	.00	.00	.00
E-THC	PPM	25.2	.0	.0	.0	.0	.0	.0	.0	.0	.0
E-CO	PPM	46.2	.0	.0	.0	.0	.0	.0	.0	.0	.0
E-NO	PPM	98.6	.0	.0	.0	.0	.0	.0	.0	.0	.0
E-NOX	PPM	97.1	.0	.0	.0	.0	.0	.0	.0	.0	.0
EGR	PCT	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
QEW	M3/MIN	11.16	.00	.00	.00	.00	.00	.00	.00	.00	.00
QED	M3/MIN	10.20	.00	.00	.00	.00	.00	.00	.00	.00	.00
QTW	M3/MIN	51.7	.0	.0	.0	.0	.0	.0	.0	.0	.0
QTD	M3/MIN	49.9	.0	.0	.0	.0	.0	.0	.0	.0	.0
D.RATIO		4.9	.0	.0	.0	.0	.0	.0	.0	.0	.0
CO2	PCT	7.8	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	87741.9	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	892.8	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KG F	3178.6	.0	.0	.0	.0	.0	.0	.0	.0	.0
THC	PPM	115.2	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	47.1	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	.479	.000	.000	.000	.000	.000	.000	.000	.000	.000
	G/KG F	1.706	.000	.000	.000	.000	.000	.000	.000	.000	.000
CO	PPM	228.8	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	163.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	1.659	.000	.000	.000	.000	.000	.000	.000	.000	.000
	G/KG F	5.91	.00	.00	.00	.00	.00	.00	.00	.00	.00
NO	PPM	487.5	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	372.2	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	3.787	.000	.000	.000	.000	.000	.000	.000	.000	.000
	G/KG F	13.485	.000	.000	.000	.000	.000	.000	.000	.000	.000
NO2	PPM	4.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	4.7	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	.048	.000	.000	.000	.000	.000	.000	.000	.000	.000
	G/KG F	.171	.000	.000	.000	.000	.000	.000	.000	.000	.000
NOX(NO2)	PPM	491.6	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	575.5	.0	.0	.0	.0	.0	.0	.0	.0	0
	G/KWH	5.856	.000	.000	.000	.000	.000	.000	.000	.000	.000
	G/KG F		.000	.000	.000			.000	.000		

E[illegible]E TYPE: ENGINE MODEL: ENGINE SERIAL NUMBER:
OPERATOR NAME: FUEL TYPE: CELL NAME: CL-5

SAMPLE		75	0	0	0	0	0	0	0	0	0
STEP		75	0	0	0	0	0	0	0	0	0
ENGSP	RPM	2084.8	.0	.0	.0	.0	.0	.0	.0	.0	.0
ETORQ	N-M	445.9	.0	.0	.0	.0	.0	.0	.0	.0	.0
CTORQ	N-M	449.8	.0	.0	.0	.0	.0	.0	.0	.0	.0
FULFA	G/S	7.63	.00	.00	.00	.00	.00	.00	.00	.00	.00
OBSFC	G/KWH	282.3	.0	.0	.0	.0	.0	.0	.0	.0	.0
CBSFC	G/KWH	279.8	.0	.0	.0	.0	.0	.0	.0	.0	.0
EXHDP	KPA	2.507	.000	.000	.000	.000	.000	.000	.000	.000	.000
LINPO	MM	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
SMOKE	PCT	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
ECO2I	PCT	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
ECO2E	PCT	7.79	.00	.00	.00	.00	.00	.00	.00	.00	.00
E-THC	PPM	25.8	.0	.0	.0	.0	.0	.0	.0	.0	.0
E-CO	PPM	47.1	.0	.0	.0	.0	.0	.0	.0	.0	.0
E-NO	PPM	91.7	.0	.0	.0	.0	.0	.0	.0	.0	.0
E-NOX	PPM	91.8	.0	.0	.0	.0	.0	.0	.0	.0	.0
EGR	PCT	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
QEW	M3/MIN	11.11	.00	.00	.00	.00	.00	.00	.00	.00	.00
QED	M3/MIN	10.15	.00	.00	.00	.00	.00	.00	.00	.00	.00
QTW	M3/MIN	51.6	.0	.0	.0	.0	.0	.0	.0	.0	.0
	M3/MIN	49.9	.0	.0	.0	.0	.0	.0	.0	.0	.0
D.RATIO		4.9	.0	.0	.0	.0	.0	.0	.0	.0	.0
CO2	PCT	7.8	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	87324.2	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	889.3	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KG F	3178.6	.0	.0	.0	.0	.0	.0	.0	.0	.0
THC	PPM	118.7	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	48.3	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	.492	.000	.000	.000	.000	.000	.000	.000	.000	.000
	G/KG F	1.757	.000	.000	.000	.000	.000	.000	.000	.000	.000
CO	PPM	233.7	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	165.8	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	1.688	.000	.000	.000	.000	.000	.000	.000	.000	.000
	G/KG F	6.03	.00	.00	.00	.00	.00	.00	.00	.00	.00
NO	PPM	455.4	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	348.2	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	3.525	.000	.000	.000	.000	.000	.000	.000	.000	.000
	G/KG F	12.601	.000	.000	.000	.000	.000	.000	.000	.000	.000
NO2	PPM	10.9	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	12.7	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	.130	.000	.000	.000	.000	.000	.000	.000	.000	.000
	G/KG F	.464	.000	.000	.000	.000	.000	.000	.000	.000	.000
NOX(NO2)	PPM	466.4	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	543.6	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	5.535	.000	.000	.000	.000	.000	.000	.000	.000	.000
	G/KG F	19.786	.000	.000	.000	.000	.000	.000	.000	.000	.000

SAMPLE DATA

ENGINE TYPE: ENGINE MODEL: ENGINE SERIAL NUMBER:
OPERATOR NAME: FUEL TYPE: CELL NAME: CL-5

SAMPLE		75	0	0	0	0	0	0	0	0	0
STEP		75	0	0	0	0	0	0	0	0	0
ENGSP	RPM	2083.8	.0	.0	.0	.0	.0	.0	.0	.0	.0
ETORQ	N-M	446.6	.0	.0	.0	.0	.0	.0	.0	.0	.0
CTORQ	N-M	450.5	.0	.0	.0	.0	.0	.0	.0	.0	.0
FULFA	G/S	7.61	.00	.00	.00	.00	.00	.00	.00	.00	.00
OBSFC	G/KWH	281.2	.0	.0	.0	.0	.0	.0	.0	.0	.0
CBSFC	G/KWH	278.8	.0	.0	.0	.0	.0	.0	.0	.0	.0
EXHDP	KPA	2.506	.000	.000	.000	.000	.000	.000	.000	.000	.000
LINPO	MM	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
SMOKE	PCT	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
ECO2I	PCT	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
ECO2E	PCT	7.73	.00	.00	.00	.00	.00	.00	.00	.00	.00
E-THC	PPM	25.3	.0	.0	.0	.0	.0	.0	.0	.0	.0
E-CO	PPM	44.7	.0	.0	.0	.0	.0	.0	.0	.0	.0
E-NO	PPM	95.1	.0	.0	.0	.0	.0	.0	.0	.0	.0
E-NOX	PPM	95.2	.0	.0	.0	.0	.0	.0	.0	.0	.0
EGR	PCT	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
QEW	M3/MIN	11.16	.00	.00	.00	.00	.00	.00	.00	.00	.00
QED	M3/MIN	10.20	.00	.00	.00	.00	.00	.00	.00	.00	.00
QTW	M3/MIN	51.7	.0	.0	.0	.0	.0	.0	.0	.0	.0
QTD	M3/MIN	49.9	.0	.0	.0	.0	.0	.0	.0	.0	.0
D.RATIO		4.9	.0	.0	.0	.0	.0	.0	.0	.0	.0
CO2	PCT	7.8	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	87109.1	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	886.1	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KG F	3178.6	.0	.0	.0	.0	.0	.0	.0	.0	.0
THC	PPM	115.3	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	47.2	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	.480	.000	.000	.000	.000	.000	.000	.000	.000	.000
	G/KG F	1.721	.000	.000	.000	.000	.000	.000	.000	.000	.000
CO	PPM	221.1	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	157.6	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	1.603	.000	.000	.000	.000	.000	.000	.000	.000	.000
	G/KG F	5.75	.00	.00	.00	.00	.00	.00	.00	.00	.00
NO	PPM	469.9	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	358.9	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	3.651	.000	.000	.000	.000	.000	.000	.000	.000	.000
	G/KG F	13.096	.000	.000	.000	.000	.000	.000	.000	.000	.000
NO2	PPM	11.7	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	13.7	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	.139	.000	.000	.000	.000	.000	.000	.000	.000	.000
	G/KG F	.498	.000	.000	.000	.000	.000	.000	.000	.000	.000
NOX(NO2)	PPM	481.6	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	564.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	5.736	.000	.000	.000	.000	.000	.000	.000	.000	.000
	G/KG F	20.579	.000	.000	.000	.000	.000	.000	.000	.000	.000

OHF - EMISSION TEST FACILITY
SAMPLE DATA
TEST INITIALIZATION VALUES

July 23 1985

[redacted]

MTU MOD 5

REPORT REQUEST DATE	07/23/85	
REPORT REQUEST TIME	11.22.50	
TEST INITIALIZATION DATE	07/23/85	
TEST INITIALIZATION TIME	11.06.23	
AVERAGING OF DATA	150 POINTS	
CELL NAME	CL-5	
TEST ID	EC8	
TEST NAME	EM8 01	
TEST DESCRIPTION	TYPE II CTCS	NEAT DIESEL 20X
ENGINE TYPE		GASEOUS
ENGINE MODEL		
ENGINE SERIAL NUMBER		
ENGINE DISPLACEMENT	12.800 LITRES	781.0 CU-IN
OPERATOR NAME	B MANIOOM	
FUEL TYPE	20X	
GAS OR DIESEL	DIESEL FUEL	
DIESEL ENGINE	NATURALLY ASPIRATED 4 STROKES	
% CARBON IN FUEL	85.900 PCT	
% HYDROGEN IN FUEL	13.810 PCT	
BACKGROUND TOTAL HYDROCARBONS	4.000 PPM	
AMBIENT DEWPOINT	0 DEG-C	32.0 DEG-F
AMBIENT VAPOR PRESSURE	1.53 KPA	.45 IN-HG
ANALYZER DEWPOINT	7.2 DEG-C	45.0 DEG-F
ANALYZER VAPOR PRESSURE	1.01 KPA	.30 IN-HG
BAROMETRIC PRESSURE	102.0 KPA	30.1 IN-HG
AMBIENT CO2	.032 PCT	
P.D. PUMP CALIBRATION FACTOR	.0315 MS/MIN-REV	
RPM OF BLOWER	1452.0 RPM	
DELAY TIME FOR ANALYZERS 1 -	11 SEC	
2 -	21 SEC	
3 -	16 SEC	
4 -	34 SEC	
5 -	46 SEC	
6 -	23 SEC	
7 -	0 SEC	
8 -	0 SEC	

ENGINE TYPE: ENGINE MODEL: ENGINE SERIAL NUMBER:
OPERATOR NAME: FUEL TYPE: CELL NAME: C1-5

SAMPLE		75	0	0	0	0	0	0	0	0	0
STEP		75	0	0	0	0	0	0	0	0	0
ENGSP	RPM	2087.3	.0	.0	.0	.0	.0	.0	.0	.0	.0
ETORQ	N-M	447.1	.0	.0	.0	.0	.0	.0	.0	.0	.0
CTORQ	N-M	449.9	.0	.0	.0	.0	.0	.0	.0	.0	.0
FULFA	G/S	7.60	.00	.00	.00	.00	.00	.00	.00	.00	.00
OBSFC	G/KWH	280.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
CBSFC	G/KWH	278.2	.0	.0	.0	.0	.0	.0	.0	.0	.0
EXHDP	KPA	2.526	.000	.000	.000	.000	.000	.000	.000	.000	.000
LINPO	MM	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
SMOKE	PCT	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
ECO2I	PCT	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
ECO2E	PCT	7.67	.00	.00	.00	.00	.00	.00	.00	.00	.00
E-THC	PPM	26.1	.0	.0	.0	.0	.0	.0	.0	.0	.0
E-CO	PPM	45.5	.0	.0	.0	.0	.0	.0	.0	.0	.0
E-NO	PPM	99.2	.0	.0	.0	.0	.0	.0	.0	.0	.0
E-NOX	PPM	98.7	.0	.0	.0	.0	.0	.0	.0	.0	.0
EGR	PCT	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
QEW	M3/MIN	11.22	.00	.00	.00	.00	.00	.00	.00	.00	.00
QED	M3/MIN	10.26	.00	.00	.00	.00	.00	.00	.00	.00	.00
QTW	M3/MIN	51.6	.0	.0	.0	.0	.0	.0	.0	.0	.0
QTD	M3/MIN	49.9	.0	.0	.0	.0	.0	.0	.0	.0	.0
D.RATIO		4.9	.0	.0	.0	.0	.0	.0	.0	.0	.0
CO2	PCT	7.7	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	86966.4	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	884.3	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KG F	3178.6	.0	.0	.0	.0	.0	.0	.0	.0	.0
THC	PPM	118.6	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	48.8	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	.496	.000	.000	.000	.000	.000	.000	.000	.000	.000
	G/KG F	1.784	.000	.000	.000	.000	.000	.000	.000	.000	.000
CO	PPM	223.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	160.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	1.627	.000	.000	.000	.000	.000	.000	.000	.000	.000
	G/KG F	5.85	.00	.00	.00	.00	.00	.00	.00	.00	.00
NO	PPM	487.0	.0	473	.0	486	0	.0	.0	.0	.0	.0
	G/H	374.2	.0	363	.0	371	.0	.0	.0	.0	.0	.0
	G/KWH	3.805	.000	3.69	.000	3.77	.00	.000	.000	.000	.000	.000
	G/KG F	13.677	.000	13.2	.000	13.5	.00	.000	.000	.000	.000	.000
NO2	PPM	8.7	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	10.3	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	.104	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	G/KG F	.375	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
NOX(NO2)	PPM	495.7	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	584.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	5.939	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	G/KG F	21.347	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000

NO Ave

Corrected

$CF = 1.0 \frac{51.6 - 49.9}{51.6} = 1.033$

$CF_{engine} = 1.0 \frac{1.01}{1021 - 1.0} = 1.010$

CF = 1.023

SAMPLE DATA

ENGINE TYPE — ENGINE MODEL — ENGINE SERIAL NUMBER
OPERATOR NAME 3 MANNION — FUEL TYPE 20X — CELL NAME CL-5

SAMPLE		73	0	0	0	0	0	0	0	0	0
STEP		73	0	0	0	0	0	0	0	0	0
ENGSP	RPM	2169.3	0	0	0	0	0	0	0	0	0
ETORQ	N-M	442.3	0	0	0	0	0	0	0	0	0
OTORQ	N-M	442.3	0	0	0	0	0	0	0	0	0
FULFW	G/S	7.71	00	00	00	00	00	00	00	00	00
SBSFC	G/KWH	253.7	0	0	0	0	0	0	0	0	0
OBSFC	G/KWH	253.7	0	0	0	0	0	0	0	0	0
EXHEF	KPA	4.111	000	000	000	000	000	000	000	000	000
LINFO	MM	0	0	0	0	0	0	0	0	0	0
AMOIS	PCT	0	0	0	0	0	0	0	0	0	0
EGRAD	PCT	3.97	00	00	00	00	00	00	00	00	00
EGRAE	PCT	7.52	00	00	00	00	00	00	00	00	00
BATHC	PPM	16.2	0	0	0	0	0	0	0	0	0
BHCO	PPM	38.2	0	0	0	0	0	0	0	0	0
BHNO	PPM	97.5	0	0	0	0	0	0	0	0	0
BHNOX	PPM	97.5	0	0	0	0	0	0	0	0	0
EIB	PCT	0	0	0	0	0	0	0	0	0	0
TEM	MG/MIN	11.85	00	00	00	00	00	00	00	00	00
TED	MG/MIN	10.42	00	00	00	00	00	00	00	00	00
TTM	MG/MIN	51.4	0	0	0	0	0	0	0	0	0
TTD	MG/MIN	50.3	0	0	0	0	0	0	0	0	0
TEFFIC		4.7	0	0	0	0	0	0	0	0	0
FUE	PCT	7.6	0	0	0	0	0	0	0	0	0
	G/H	39167.6	0	0	0	0	0	0	0	0	0
	G/KWH	401.6	0	0	0	0	0	0	0	0	0
	G/G F	3178.7	0	0	0	0	0	0	0	0	0
TMF	RPM	73.4	0	0	0	0	0	0	0	0	0
	G/H	31.2	0	0	0	0	0	0	0	0	0
	G/KWH	319	000	000	000	000	000	000	000	000	000
	G/G F	1.123	00	000	000	000	000	000	000	000	000
TD	RPM	181.7	0	0	0	0	0	0	0	0	0
	G/H	15.3	0	0	0	0	0	0	0	0	0
	G/KWH	156	000	000	000	000	000	000	000	000	000
	G/G F	4.55	00	00	00	00	00	00	00	00	00
TF	RPM	419.5	0	0	0	0	0	0	0	0	0
	G/H	333.0	0	0	0	0	0	0	0	0	0
	G/KWH	3.411	000	000	000	000	000	000	000	000	000
	G/G F	12.024	000	000	000	000	000	000	000	000	000
TFC	RPM	2.0	0	0	0	0	0	0	0	0	0
	G/H	5.0	0	0	0	0	0	0	0	0	0
	G/KWH	052	000	000	000	000	000	000	000	000	000
	G/G F	238	000	000	000	000	000	000	000	000	000
[illegible]	RPM	426.1 NOX	0	0	0	0	0	0	0	0	0
	G/H	319.5	0	0	0	0	0	0	0	0	0
	G/KWH	3.311	000	000	000	000	000	000	000	000	000
	G/G F	13.724	000	000	000	000	000	000	000	000	000

and

[illegible] - EMISSION TEST FACILITY
SAMPLE BATH

ENGINE TYPE
OPERATOR NAME [illegible]
ENGINE FUEL
FUEL TYPE 2DA
ENGINE SERIAL NUMBER
CELL NAME CL-3

SAMPLE		75	0	0	0	0	0	0	0	0	0
STEP		75	0	0	0	0	0	0	0	0	0
ENGSP	RPM	2111.9	0	0	0	0	0	0	0	0	0
ETORQ	N-M	443.3	0	0	0	0	0	0	0	0	0
DTORQ	N-M	442.9	0	0	0	0	0	0	0	0	0
PULSE	0.0	7.00	00	00	00	00	00	00	00	00	00
VEEPC	0-5VDC	282.9	0	0	0	0	0	0	0	0	0
VEEPC	0-5VDC	282.9	0	0	0	0	0	0	0	0	0
EXHEF	KPH	7.000	000	000	000	000	000	000	000	000	000
EXHFO	KPH	0	0	0	0	0	0	0	0	0	0
SMOKE	PCT	0	0	0	0	0	0	0	0	0	0
EXHO2	PCT	3.67	00	00	00	00	00	00	00	00	00
EXH2E	PCT	7.43	00	00	00	00	00	00	00	00	00
EXTHC	PPM	17.4	0	0	0	0	0	0	0	0	0
EXCO	PPM	33.4	0	0	0	0	0	0	0	0	0
EXNO	PPM	40.1	0	0	0	0	0	0	0	0	0
EXNOX	PPM	40.1	0	0	0	0	0	0	0	0	0
EGR	PCT	0	0	0	0	0	0	0	0	0	0
TEA	MG/MIN	11.09	00	00	00	00	00	00	00	00	00
WED	MG/MIN	00.72	00	00	00	00	00	00	00	00	00
DTA	MG/MIN	0.3	0	0	0	0	0	0	0	0	0
DTD	MG/MIN	0.3	0	0	0	0	0	0	0	0	0
D RATIO		0.7	0	0	0	0	0	0	0	0	0
CO2	PCT	7.5	0	0	0	0	0	0	0	0	0
	G/M	97456.9	0	0	0	0	0	0	0	0	0
	G/HP	944.0	0	0	0	0	0	0	0	0	0
	G/HP-H	9178.7	0	0	0	0	0	0	0	0	0
THC	PPM	74.9	0	0	0	0	0	0	0	0	0
	G/M	10.9	0	0	0	0	0	0	0	0	0
	G/HP	311	000	000	000	000	000	000	000	000	000
	G/HP-H	3121	000	000	000	000	000	000	000	000	000
CO	PPM	[illegible]	0	0	0	0	0	0	0	0	0
	G/M	[illegible]	0	0	0	0	0	0	0	0	0
	G/HP	[illegible]	000	000	000	000	000	000	000	000	000
	G/HP-H	4.22	00	00	00	00	00	00	00	00	00
NO	PPM	400.1	0	0	0	0	0	0	0	0	0
	G/M	365.5	0	0	0	0	0	0	0	0	0
	G/HP	3.716	000	000	000	000	000	000	000	000	000
	G/HP-H	38.208	000	000	000	000	000	000	000	000	000
NO2	PPM	4.0	0	0	0	0	0	0	0	0	0
	G/M	11.1	0	0	0	0	0	0	0	0	0
	G/HP	114	000	000	000	000	000	000	000	000	000
	G/HP-H	401	000	000	000	000	000	000	000	000	000
NOX(NO2)	PPM	404.1	0	0	0	0	0	0	0	0	0
	G/M	371.5	0	0	0	0	0	0	0	0	0
	G/HP	3.842	000	000	000	000	000	000	000	000	000
	G/HP-H	39.579	000	000	000	000	000	000	000	000	000

[illegible] EMISSION TEST FACILITY

SAMPLE DATA

ENGINE TYPE [illegible] — ENGINE SERIAL NUMBER
OPERATOR NAME [illegible] — FUEL TYPE JP4 — CELL NAME CL-3

SAMPLE		75	0	0	0	0	0	0	0	0	0
STEP		75	0	0	0	0	0	0	0	0	0
ENGSP	RPM	2102.5	0	0	0	0	0	0	0	0	0
ETORQ	N-M	444.0	0	0	0	0	0	0	0	0	0
ETORQ	N-M	445.0	0	0	0	0	0	0	0	0	0
FULFR	G/S	7.65	00	00	00	00	00	00	00	00	00
UEXFL	G/KGM	283.0	0	0	0	0	0	0	0	0	0
UEXFL	G/KGM	281.9	0	0	0	0	0	0	0	0	0
EXHFP	KPA	7.101	000	000	000	000	000	000	000	000	000
LINFO	PH	0	0	0	0	0	0	0	0	0	0
SMOKE	PCT	0	0	0	0	0	0	0	0	0	0
EGR01	PCT	3.19	00	00	00	00	00	00	00	00	00
EGR02	PCT	7.24	00	00	00	00	00	00	00	00	00
E-THC	PPM	16.5	0	0	0	0	0	0	0	0	0
E-CO	PPM	49.5	0	0	0	0	0	0	0	0	0	0
E-NOX	PPM	38.7	0	0	0	0	0	0	0	0	0
E-NOX	PPM	38.5	0	0	0	0	0	0	0	0	0
EGR	PCT	0	0	0	0	0	0	0	0	0	0
CO2	MG/KGM	11.28	00	00	00	00	00	00	00	00	00
CO	MG/KGM	11.35	00	00	00	00	00	00	00	00	00
THC	MG/KGM	5.3	0	0	0	0	0	0	0	0	0
NOX	MG/KGM	5.3	0	0	0	0	0	0	0	0	0
RATIO		4.9	4.86	0	0	0	0	0	0	0	0
CO2	PCT	7.7	0	0	0	0	0	0	0	0	0
	G/M	9743.4	0	0	0	0	0	0	0	0	0
	G/KGM	349.0	0	0	0	0	0	0	0	0	0
	G/KG F	3173.7	0	0	0	0	0	0	0	0	0
THC	PPM	76.5	0	0	0	0	0	0	0	0	0
	G/M	31.7	0	0	0	0	0	0	0	0	0
	G/KGM	1.13	000	000	000	000	000	000	000	000	000
	G/KG F	1.147	000	000	000	000	000	000	000	000	000
CO	PPM	144.1	0	0	0	0	0	0	0	0	0
	G/M	178.2	0	0	0	0	0	0	0	0	0
	G/KGM	1.3[illegible]	000	000	000	000	000	000	000	000	000
	G/KG F	0.38	00	00	00	00	00	00	00	00	00
			Corrected (1.019)								
NO	PPM	434.5	443.1	0	0	0	0	0	0	0	0
	G/M	337.0	NO 343.4	0	0	0	0	0	0	0	0
	G/KGM	3.434	3.50	000	000	000	000	000	000	000	000
	G/KG F	12.183	12.41	000	000	000	000	000	000	000	000
HC	PPM	7.5	0	0	0	0	0	0	0	0	0
	G/M	9.0	0	0	0	0	0	0	0	0	0
	G/KGM	091	000	000	000	000	000	000	000	000	000
	G/KG F	324	000	000	000	000	000	000	000	000	000
NOX(HOT)	PPM	442.4	0	0	0	0	0	0	0	0	0
	G/M	325.7	0	0	0	0	0	0	0	0	0
	G/KGM	3.337	000	000	000	000	000	000	000	000	000
	G/KG F	11.833	000	000	00	000	000	000	000	000	000

58 ppm SO2

DRF - EMISSION TEST FACILITY PAGE 1

SAMPLE DATA

ENGINE TYPE — ENGINE MODEL — ENGINE SERIAL NUMBER

OPERATOR NAME: B MANICOM — FUEL TYPE: 20X — CELL NAME: CL-3

SAMPLE		73	0	0	0	0	0	0	0	0	0
STEP		73	0	0	0	0	0	0	0	0	0
ENGSP	RPM	2103.0	0	0	0	0	0	0	0	0	0
ETORQ	N-M	446.0	0	0	0	0	0	0	0	0	0
ITORQ	N-M	443.3	0	0	0	0	0	0	0	0	0
FULFR	G/S	7.67	00	00	00	00	00	00	00	00	00
DBSFC	G/KWH	281.6	0	0	0	0	0	0	0	0	0
CBSFC	G/KWH	282.1	0	0	0	0	0	0	0	0	0
EXHEF	LFQ	5.034	000	000	000	000	000	000	000	000	000
LINFQ	MM	0	0	0	0	0	0	0	0	0	0
AMBTE	DGT	0	0	0	0	0	0	0	0	0	0
ECOOL	DGT	3.00	00	00	00	00	00	00	00	00	00
EOILE	DGT	7.30	00	00	00	00	00	00	00	00	00
E-THC	PPM	13.6	0	0	0	0	0	0	0	0	0
E-CO	PPM	40.9	0	0	0	0	0	0	0	0	0
E-NO	PPM	16.9	0	0	0	0	0	0	0	0	0
E-NOX	PPM	16.9	0	0	0	0	0	0	0	0	0
EGR	PCT	0	0	0	0	0	0	0	0	0	0
VEW	M3/MIN	11.81	00	00	00	00	00	00	00	00	00
VEE	M3/MIN	10.68	00	00	00	00	00	00	00	00	00
VTW	M3/MIN	51.9	0	0	0	0	0	0	0	0	0
VTE	M3/MIN	50.3	0	0	0	0	0	0	0	0	0
E RATIO		4.6	0	0	0	0	0	0	0	0	0
CO2	PCT	7.3	0	0	0	0	0	0	0	0	0
	G/H	37723.2	0	0	0	0	0	0	0	0	0
	G/KWH	396.4	0	0	0	0	0	0	0	0	0
	G/G F	3173.7	0	0	0	0	0	0	0	0	0
THC	PPM	72.3	0	0	0	0	0	0	0	0	0
	G/H	32.0	0	0	0	0	0	0	0	0	0
	G/KWH	327	000	000	000	000	000	000	000	000	000
	G/G F	1.157	000	000	000	000	000	000	000	000	000
CO	PPM	218.9	0	0	0	0	0	0	0	0	0
	G/H	100.4	0	0	0	0	0	0	0	0	0
	G/KWH	1.791	000	000	000	000	000	000	000	000	000
	G/G F	6.33	00	00	00	00	00	00	00	00	00
NO	PPM	448.7	0	0	0	0	0	0	0	0	0
	G/H	365.3	0	0	0	0	0	0	0	0	0
	G/KWH	3.735	000	000	000	000	000	000	000	000	000
	G/G F	13.245	000	000	000	000	000	000	000	000	000
NO2	PPM	5.4	0	0	0	0	0	0	0	0	0
	G/H	10.5	0	0	0	0	0	0	0	0	0	0
	G/KWH	107	000	000	000	000	000	000	000	000	000
	G/G F	379	000	000	000	000	000	000	000	000	000
NOX(NO2)	PPM	477.0	NOx 0	0	0	0	0	0	0	0	0
	G/H	371.0	0	0	0	0	0	0	0	0	0
	G/KWH	3.833	000	000	000	000	000	000	000	000	000
	G/G F	13.587	000	000	000	000	000	000	000	000	000

SAMPLE DATA

ENGINE TYPE ENGINE MODEL ENGINE SERIAL NUMBER
OPERATOR NAME S MANUCCI FUEL TYPE 2DA CELL NAME CL-3

SAMPLE		73	0	0	0	0	0	0	0	0	0
STEP		75	0	0	0	0	0	0	0	0	0
ENGSP	RPM	2116.4	0	0	0	0	0	0	0	0	0
ETORQ	N-M	445.1	0	0	0	0	0	0	0	0	0
DTORQ	N-M	445.2	0	0	0	0	0	0	0	0	0
FUELA	G/S	7.56	00	00	00	00	00	00	00	00	00
IBSFC	G/KWH	281.0	0	0	0	0	0	0	0	0	0
IBSFC	G/KWH	280.9	0	0	0	0	0	0	0	0	0
ENGP	KPA	5.210	000	000	000	000	000	000	000	000	000
LIMIT	MM	0	0	0	0	0	0	0	0	0	0
SMOKE	PCT	0	0	0	0	0	0	0	0	0	0
ECOZ1	PCT	3.67	00	00	00	00	00	00	00	00	00
ECO2E	PCT	7.70	00	00	00	00	00	00	00	00	00
E-THC	PPM	18.4	0	0	0	0	0	0	0	0	0
E-CO	PPM	46.4	0	0	0	0	0	0	0	0	0
E-NO	PPM	97.1	0	0	0	0	0	0	0	0	0
E-NOX	PPM	85.4	0	0	0	0	0	0	0	0	0
EXH	PCT	0	0	0	0	0	0	0	0	0	0
TEM	MB MIN	11.22	00	00	00	00	00	00	00	00	00
TBO	MB MIN	10.95	00	00	00	00	00	00	00	00	00
ITM	MB-MIN	91.6	0	0	0	0	0	0	0	0	0
ITB	MB-MIN	90.3	0	0	0	0	0	0	0	0	0
FLRATIO		4.5	0	0	0	0	0	0	0	0	0
CO2	PCT	~~7.7~~	0	0	0	0	0	0	0	0	0
	G/H	~~9767.7~~	0	0	0	0	0	0	0	0	0
	G/KWH	~~[illegible]~~	0	0	0	0	0	0	0	0	0
	G/G F	1.173	0	0	0	0	0	0	0	0	0
THC	PPM	76.2	0	0	0	0	0	0	0	0	0
	G/H	31.5	0	0	0	0	0	0	0	0	0
	G/KWH	320	000	000	000	000	000	000	000	000	000
	G/G F	1.141	000	000	000	000	000	000	000	000	000
CO	PPM	226.9	0	0	0	0	0	0	0	0	0
	G/H	171.2	0	0	0	0	0	0	0	0	0
	G/KWH	1.748	000	000	000	000	000	000	000	000	000
	G/G F	6.23	00	00	00	00	00	00	00	00	00
NO	PPM	439.1	No Correction (X 1.019)								
	G/H	338.8	447	0	0	0	0	0	0	0	0
	G/KWH	3.448	345	0	0	0	0	0	0	0	0
	G/G F	12.282	3.51	000	000	000	000	000	000	000	000
			12.52	000	000	000	000	000	000	000	000
NOZ	PPM	7.6	0	0	0	0	0	0	0	0	0
	G/H	4.3	0	0	0	0	0	0	0	0	0
	G/KWH	.044	000	000	000	000	000	000	000	000	000
	G/G F	.016	000	000	000	000	000	000	000	000	000
NOX	PPM	447.0	0	0	0	0	0	0	0	0	0
	G/H	343.7	0	0	0	0	0	0	0	0	0
	G/KWH	3.493	000	000	000	000	000	000	000	000	000
	G/G F	12.448	000	000	000	000	000	000	000	000	000

ORF - EMISSION TEST FACILITY
SAMPLE DATA
TEST INITIALIZATION VALUES

REPORT REQUEST DATE:	08/14/85	
REPORT REQUEST TIME:	15:16:36	
TEST INITIALIZATION DATE:	08/14/85	
TEST INITIALIZATION TIME:	15:07:24	
AVERAGING OF DATA:	150 POINTS	
CELL NAME:	CL-5	
TEST ID:	ECS	
TEST NAME:	EMS 01	
TEST DESCRIPTION:	TYPE II CTOS	90 MG CERIUM
ENGINE TYPE:		
ENGINE MODEL:		
ENGINE SERIAL NUMBER:		
ENGINE DISPLACEMENT:	12.800 LITRES	781.0 CU-IN
OPERATOR NAME:	MAHICOM	
FUEL TYPE:	20%	
GAS OR DIESEL :	DIESEL FUEL	
DIESEL ENGINE:	NATURALLY ASPIRATED 4 STROKES	
% CARBON IN FUEL:	85.900 PCT	
% HYDROGEN IN FUEL:	13.810 PCT	
BACKGROUND TOTAL HYDROCARBONS:	8.000 PPM	
AMBIENT DEWPOINT:	.0 DEG-C	32.0 DEG-F
AMBIENT VAPOR PRESSURE:	1.83 KPA	.54 IN-HG
ANALYZER DEWPOINT:	7.2 DEG-C	45.0 DEG-F
ANALYZER VAPOR PRESSURE	1.01 KPA	.30 IN-HG
BAROMETRIC PRESSURE:	101.7 KPA	30.0 IN-HG
AMBIENT CO2:	.032 PCT	
P.D. PUMP CALIBRATION FACTOR:	.0313 M3/MIN-REV	
RPM OF BLOWER:	1952.0 RPM	
DELAY TIME FOR ANALYZERS: 1 -	11 SEC	
2 -	21 SEC	
3 -	16 SEC	
4 -	34 SEC	
5 -	46 SEC	
6 -	23 SEC	
7 -	0 SEC	
8 -	0 SEC	

Aug 14 '85

[redacted]

MTU MOD 5

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ORF - EMISSION TEST FACILITY
SAMPLE DATA

ENGINE TYPE: ENGINE MODEL: ENGINE SERIAL NUMBER:
OPERATOR NAME: MANICOM FUEL TYPE: 20% CELL NAME: CL-5

SAMPLE		75	0	0	0	0	0	0	0	0	0
STEP		75	0	0	0	0	0	0	0	0	0
ENGSP	RPM	2057.7	.0	.0	.0	.0	.0	.0	.0	.0	.0
ETORQ	N-M	446.7	.0	.0	.0	.0	.0	.0	.0	.0	.0
CTORQ	N-M	451.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
FULFA	G/S	7.50	.00	.00	.00	.00	.00	.00	.00	.00	.00
OBSFC	G/KWH	280.6	.0	.0	.0	.0	.0	.0	.0	.0	.0
CBSFC	G/KWH	278.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
EXHOP	KPA	3.355	.000	.000	.000	.000	.000	.000	.000	.000	.000
LINPO	MM	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
SMOKE	PCT	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
EC02I	PCT	1.80	.00	.00	.00	.00	.00	.00	.00	.00	.00
EC02E	PCT	8.05	.00	.00	.00	.00	.00	.00	.00	.00	.00
E-THC	PPM	22.1	.0	.0	.0	.0	.0	.0	.0	.0	.0
E-CO	PPM	48.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
E-NO	PPM	86.9	.0	.0	.0	.0	.0	.0	.0	.0	.0
E-NOX	PPM	86.9	.0	.0	.0	.0	.0	.0	.0	.0	.0
EGR	PCT	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
QEW	M3/MIN	10.59	.00	.00	.00	.00	.00	.00	.00	.00	.00
QED	M3/MIN	9.66	.00	.00	.00	.00	.00	.00	.00	.00	.00
QTW	M3/MIN	51.5	.0	.0	.0	.0	.0	.0	.0	.0	.0
	M3/MIN	49.8	.0	.0	.0	.0	.0	.0	.0	.0	.0
D.RATIO		5.2 5.155	.0	.0	.0	.0	.0	.0	.0	.0	.0
CO2	PCT	8.1	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	85857.2	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	883.4	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KG F	3178.8	.0	.0	.0	.0	.0	.0	.0	.0	.0
THC	PPM	83.0 THC	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	32.1	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	.331	.000	.000	.000	.000	.000	.000	.000	.000	.000
	G/KG F	1.190	.000	.000	.000	.000	.000	.000	.000	.000	.000
CO	PPM	249.9 CO	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	168.7	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	1.736	.000	.000	.000	.000	.000	.000	.000	.000	.000
	G/KG F	6.25	.00	.00	.00	.00	.00	.00	.00	.00	.00
NO	PPM	452.6	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	327.3	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	3.367	.000	.000	.000	.000	.000	.000	.000	.000	.000
	G/KG F	12.117	.000	.000	.000	.000	.000	.000	.000	.000	.000
NO2	PPM	10.2	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	11.4	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	.117	.000	.000	.000	.000	.000	.000	.000	.000	.000
	G/KG F	.420	.000	.000	.000	.000	.000	.000	.000	.000	.000
			NOx								
NOX(NO2)	PPM	462.8	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	513.2	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	5.280	.000	.000	.000	.000	.000	.000	.000	.000	.000
	G/KG F	19.000	.000	.000	.000	.000	.000	.000	.000	.000	.000

ORF - EMISSION TEST FACILITY
SAMPLE DATA

ENGINE TYPE: ENGINE MODEL: ENGINE SERIAL NUMBER:
OPERATOR NAME: MANICOM FUEL TYPE: 20% CELL NAME: CL-5

SAMPLE		75	0	0	0	0	0	0	0	0	0
STEP		75	0	0	0	0	0	0	0	0	0
ENGSP	RPM	2057.2	.0	.0	.0	.0	.0	.0	.0	.0	.0
ETORQ	N-M	440.3	.0	.0	.0	.0	.0	.0	.0	.0	.0
CTORQ	N-M	444.2	.0	.0	.0	.0	.0	.0	.0	.0	.0
FULFA	G/S	7.47	.00	.00	.00	.00	.00	.00	.00	.00	.00
OBSFC	G/KWH	283.4	.0	.0	.0	.0	.0	.0	.0	.0	.0
CBSFC	G/KWH	280.9	.0	.0	.0	.0	.0	.0	.0	.0	.0
EXHDP	KPA	5.368	.000	.000	.000	.000	.000	.000	.000	.000	.000
LINPO	MM	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
SMOKE	PCT	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
EC02I	PCT	1.79	.00	.00	.00	.00	.00	.00	.00	.00	.00
EC02E	PCT	8.08	.00	.00	.00	.00	.00	.00	.00	.00	.00
E-THC	PPM	21.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
E-CO	PPM	48.7	.0	.0	.0	.0	.0	.0	.0	.0	.0
E-NO	PPM	86.5	.0	.0	.0	.0	.0	.0	.0	.0	.0
E-NOX	PPM	86.7	.0	.0	.0	.0	.0	.0	.0	.0	.0
EGR	PCT	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
QEW	M3/MIN	10.49	.00	.00	.00	.00	.00	.00	.00	.00	.00
QED	M3/MIN	9.57	.00	.00	.00	.00	.00	.00	.00	.00	.00
QTW	M3/MIN	51.4	.0	.0	.0	.0	.0	.0	.0	.0	.0
QTD	M3/MIN	49.8	.0	.0	.0	.0	.0	.0	.0	.0	.0
D RATIO		5.2 5.17	.0	.0	.0	.0	.0	.0	.0	.0	.0
C02	PCT	8.1	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	85442.9	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	892.8	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KG F	3178.8	.0	.0	.0	.0	.0	.0	.0	.0	.0
THC	PPM	78.3 THC	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	29.9	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	.313	.000	.000	.000	.000	.000	.000	.000	.000	.000
	G/KG F	1.114	.000	.000	.000	.000	.000	.000	.000	.000	.000
CO	PPM	255.8 CO	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	171.1	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	1.787	.000	.000	.000	.000	.000	.000	.000	.000	.000
	G/KG F	6.36	.00	.00	.00	.00	.00	.00	.00	.00	.00
NO	PPM	454.7	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	325.8	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	3.404	.000	.000	.000	.000	.000	.000	.000	.000	.000
	G/KG F	12.119	.000	.000	.000	.000	.000	.000	.000	.000	.000
NO2	PPM	10.7	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	11.8	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	.123	.000	.000	.000	.000	.000	.000	.000	.000	.000
	G/KG F	.438	.000	.000	.000	.000	.000	.000	.000	.000	.000
NOX(NO2)	PPM	465.4 NOx	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	511.3	.0	.0	0	.0	.0	.0	.0	.0	.0
	G/KWH	5.342	.000	.000		000	.000	.000	.0	0.0	000
			000				000				

SAMPLE DATA

ENGINE TYPE: ENGINE MODEL: ENGINE SERIAL NUMBER:
OPERATOR NAME: MANICOM FUEL TYPE: 20% CELL NAME: CL-5

SAMPLE		75	0	0	0	0	0	0	0	0	0
STEP		75	0	0	0	0	0	0	0	0	0
ENGSP	RPM	2050.6	.0	.0	.0	.0	.0	.0	.0	.0	.0
ETORQ	N-M	446.1	.0	.0	.0	.0	.0	.0	.0	.0	.0
CTORQ	N-M	451.2	.0	.0	.0	.0	.0	.0	.0	.0	.0
FULFA	G/S	7.47	.00	.00	.00	.00	.00	.00	.00	.00	.00
OBSFC	G/KWH	280.8	.0	.0	.0	.0	.0	.0	.0	.0	.0
CBSFC	G/KWH	277.6	.0	.0	.0	.0	.0	.0	.0	.0	.0
EXHDP	KPA	3.364	.000	.000	.000	.000	.000	.000	.000	.000	.000
LINPO	MM	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
SMOKE	PCT	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
ECO2I	PCT	1.79	.00	.00	.00	.00	.00	.00	.00	.00	.00
ECO2E	PCT	8.11	.00	.00	.00	.00	.00	.00	.00	.00	.00
E-THC	PPM	21.4	.0	.0	.0	.0	.0	.0	.0	.0	.0
E-CO	PPM	50.3	.0	.0	.0	.0	.0	.0	.0	.0	.0
E-NO	PPM	85.7	.0	.0	.0	.0	.0	.0	.0	.0	.0
E-NOX	PPM	85.6	.0	.0	.0	.0	.0	.0	.0	.0	.0
EGR	PCT	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
QEW	M3/MIN	10.46	.00	.00	.00	.00	.00	.00	.00	.00	.00
QED	M3/MIN	9.54	.00	.00	.00	.00	.00	.00	.00	.00	.00
QTM	M3/MIN	51.4	.0	.0	.0	.0	.0	.0	.0	.0	.0
	M3/MIN	49.7	.0	.0	.0	.0	.0	.0	.0	.0	.0
D.RATIO		5.2	5.2 .0	.0	.0	.0	.0	.0	.0	.0	.0
CO2	PCT	8.2	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	85494.6	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	882.3	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KG F	3178.8	.0	.0	.0	.0	.0	.0	.0	.0	.0
THC	PPM	80.0	THC .0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	30.6	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	.316	.000	.000	.000	.000	.000	.000	.000	.000	.000
	G/KG F	1.137	.000	.000	.000	.000	.000	.000	.000	.000	.000
CO	PPM	264.8	CO .0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	176.3	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	1.820	.000	.000	.000	.000	.000	.000	.000	.000	.000
	G/KG F	6.56	.00	.00	.00	.00	.00	.00	.00	.00	.00
NO	PPM	451.5	NO .0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	322.3	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	3.326	.000	.000	.000	.000	.000	.000	.000	.000	.000
	G/KG F	11.984	.000	.000	.000	.000	.000	.000	.000	.000	.000
NO2	PPM	9.4	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	10.3	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	.106	.000	.000	.000	.000	.000	.000	.000	.000	.000
	G/KG F	.383	.000	.000	.000	.000	.000	.000	.000	.000	.000
NOX(NO2)	PPM	460.9	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	504.5	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	5.207	.000	.000	.000	.000	.000	.000	.000	.000	.000
	G/KG F	18.759	.000	.000	.000	.000	.000	.000	.000	.000	.000

SAMPLE DATA

ENGINE TYPE: ENGINE MODEL: ENGINE SERIAL NUMBER:
OPERATOR NAME: MANICOM FUEL TYPE: 20% CELL NAME: CL-5

SAMPLE		75	0	0	0	0	0	0	0	0	0
STEP		75	0	0	0	0	0	0	0	0	0
ENGSP	RPM	2049.9	.0	.0	.0	.0	.0	.0	.0	.0	.0
ETORQ	N-M	446.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
CTORQ	N-M	450.4	.0	.0	.0	.0	.0	.0	.0	.0	.0
FULFA	G/S	7.46	.00	.00	.00	.00	.00	.00	.00	.00	.00
OBSFC	G/KWH	280.5	.0	.0	.0	.0	.0	.0	.0	.0	.0
CBSFC	G/KWH	277.7	.0	.0	.0	.0	.0	.0	.0	.0	.0
EXHDP	KPA	5.464	.000	.000	.000	.000	.000	.000	.000	.000	.000
LINPO	MM	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
SMOKE	PCT	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
ECO2I	PCT	1.79	.00	.00	.00	.00	.00	.00	.00	.00	.00
ECO2E	PCT	8.07	.00	.00	.00	.00	.00	.00	.00	.00	.00
E-THC	PPM	21.2	.0	.0	.0	.0	.0	.0	.0	.0	.0
E-CO	PPM	52.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
E-NO	PPM	83.4	.0	.0	.0	.0	.0	.0	.0	.0	.0
E-NOX	PPM	83.4	.0	.0	.0	.0	.0	.0	.0	.0	.0
EGR	PCT	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
QEW	M3/MIN	10.50	.00	.00	.00	.00	.00	.00	.00	.00	.00
QED	M3/MIN	9.57	.00	.00	.00	.00	.00	.00	.00	.00	.00
QTW	M3/MIN	51.4	.0	.0	.0	.0	.0	.0	.0	.0	.0
QTD	M3/MIN	49.7	.0	.0	.0	.0	.0	.0	.0	.0	.0
D RATIO		5.2	5.19 .0	.0	.0	.0	.0	.0	.0	.0	.0
CO2	PCT	8.1	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	85356.6	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	882.7	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KG F	3178.8	.0	.0	.0	.0	.0	.0	.0	.0	.0
THC	PPM	78.9	THC .0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	30.3	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	.313	.000	.000	.000	.000	.000	.000	.000	.000	.000
	G/KG F	1.128	.000	.000	.000	.000	.000	.000	.000	.000	.000
CO	PPM	272.6	CO .0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	182.4	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	1.886	.000	.000	.000	.000	.000	.000	.000	.000	.000
	G/KG F	6.79	.00	.00	.00	.00	.00	.00	.00	.00	.00
NO	PPM	437.7	NO .0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	313.8	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	3.245	.000	.000	.000	.000	.000	.000	.000	.000	.000
	G/KG F	11.686	.000	.000	.000	.000	.000	.000	.000	.000	.000
NO2	PPM	9.4	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	10.3	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	.107	.000	.000	.000	.000	.000	.000	.000	.000	.000
	G/KG F	.385	.000	.000	.000	.000	.000	.000	.000	.000	.000
NOX(NO2)	PPM	447.1	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	491.5	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	5.083	.000	.000	.000	.000	.000	.000	000	.000	.000
	G/KG F	[illegible]	000	.000	000	.000	.000	000	[illegible]	000	.000

ORF - EMISSION TEST FACILITY
SAMPLE DATA

ENGINE TYPE: ENGINE MODEL: ENGINE SERIAL NUMBER:
O TOR NAME: MANICOM FUEL TYPE: 20X CELL NAME: CL-5

SAMPLE		75	0	0	0	0	0	0	0	0	0
STEP		75	0	0	0	0	0	0	0	0	0
ENGSP	RPM	2073.8	.0	.0	.0	.0	.0	.0	.0	.0	.0
ETORQ	N-M	446.7	.0	.0	.0	.0	.0	.0	.0	.0	.0
CTORQ	N-M	450.5		.0	.0	.0	.0	.0	.0	.0	.0
FULFA	G/S	7.56	97.8 kW	.00	.00	.00	.00	.00	.00	.00	.00
OBSFC	G/KWH	280.7	.0	.0	.0	.0	.0	.0	.0	.0	.0
CBSFC	G/KWH	278.3	.0	.0	.0	.0	.0	.0	.0	.0	.0
EXHDP	KPA	3.429	.000	.000	.000	.000	.000	.000	.000	.000	.000
LINPO	MM	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
SMOKE	PCT	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
EC02I	PCT	1.79	.00	.00	.00	.00	.00	.00	.00	.00	.00
EC02E	PCT	8.05	.00	.00	.00	.00	.00	.00	.00	.00	.00
E-THC	PPM	20.9	.0	.0	.0	.0	.0	.0	.0	.0	.0
E-CO	PPM	51.6	.0	.0	.0	.0	.0	.0	.0	.0	.0
E-NO	PPM	82.6	.0	.0	.0	.0	.0	.0	.0	.0	.0
E-NOX	PPM	82.8	.0	.0	.0	.0	.0	.0	.0	.0	.0
EGR	PCT	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
QEW	M3/MIN	10.66	.00	.00	.00	.00	.00	.00	.00	.00	.00
QED	M3/MIN	9.73	.00	.00	.00	.00	.00	.00	.00	.00	.00
QTW	M3/MIN	51.3	.0	.0	.0	.0	.0	.0	.0	.0	.0
	M3/MIN	49.7	.0	.0	.0	.0	.0	.0	.0	.0	.0
A/F RATIO		5.1	5.11 .0	.0	.0	.0	.0	.0	.0	.0	.0
CO2	PCT	8.1	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	86535.8	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	884.5	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KG F	3178.8	.0	.0	.0	.0	.0	.0	.0	.0	.0
THC	PPM	75.9	THC .0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	29.6	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	.302	.000	.000	.000	.000	.000	.000	.000	.000	.000
	G/KG F	1.087	.000	.000	.000	.000	.000	.000	.000	.000	.000
CO	PPM	266.1	CO .0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	180.9	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	1.849	.000	.000	.000	.000	.000	.000	.000	.000	.000
	G/KG F	6.65	.00	NO .00	.00	Corrected .00	.00	.00	.00	.00	.00
NO	PPM	426.1	NO .0	Average 437.0	.0	446 .0	.0	.0	.0	.0	.0
	G/H	310.4	.0	316 .0	.0	322 .0	.0	.0	.0	.0	.0
	G/KWH	3.172	.000	3.25.000	.000	3.31.000	.000	.000	.000	.000	.000
	G/KG F	11.401	.000	11.7.000	.000	11.9.300	.000	.000	.000	.000	.000
NO2	PPM	10.2	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	11.4	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	.116	.000	.000	.000	.000	.000	.000	.000	.000	.000
	G/KG F	.418	.000	.000	.000	.000	.000	.000	.000	.000	.000
NOX(NO2)	PPM	436.2	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/H	487.3	.0	.0	.0	.0	.0	.0	.0	.0	.0
	G/KWH	4.981	.000	.000	.000	.000	.000	.000	.000	.000	.000
	G/KG F	17.900	.000	.000	.000	.000	.000	.000	.000	.000	.000

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ENGINEERING SCIENCES DIVISION

Centre for Alternative Fuel Utilization

DRAFT
REPORT ON THE TESTING OF PARTICULATE OXIDIZER TRAP #2

Report No.4591
ES/CAFU/85-44

Submitted to:

Engine Control Systems
P.O. Box 458
Aurora, Ontario
L4G 3L5

Attention: Mr. Fred Kieran.

K. Ha
B. Manicom

October 8, 1985.

RESEARCH

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1. SUMMARY

Testing to evaluate the performance of an ECS-JMI Particulate Oxidizer Trap Type II (POT II) was completed.

The particulate ignition temperature using neat diesel fuel, was found to be around 450°C for the right and left exhaust banks respectively. Ignition temperature using fuel additive (manganese, cerium) at different concentrations (60 mg Mn, 80 mg Mn, 45 mg Ce and 90 mg Ce/L diesel) resulted only in minor changes in ignition temperature.

The average exhaust backpressure build-up rate during the MTU-LHD (MOD 5) cycle was .33 kPa/hr using neat diesel and .28 kPa/hr using 90 mg Ce/L diesel.

The sulphate testing indicates no significant convertion of SO_2 to sulphate.

The total particulate removal efficiency is 65.1% using neat diesel fuel and 72.3% using 90 mg Ce/L diesel.

The use of POT II reduces EQI from 321 to 178 using neat diesel and to 184 using 90 mg Ce/L diesel.

In using 90 mg Ce/L diesel, 14.5% of cerium was measured after the POT II.

Both the neat diesel and the 90 mg Ce/L diesel produced negative and non-mutagenic results for salmonella tester strain TA-98 without metabolic activation.

2. INTRODUCTION

The testing of the ECS-JMI POT II was carried out under contract from ECS. The POTs arrived at ORF in July and testing was completed late August.

The POTs were installed on exhaust bands of a Deutz F8L 413 F/W air-cooled engine (S/N 6284019). This engine was used due to its popularity in underground mines.

The testing was conducted in the following sequential order:

1. Exhaust Backpressure Build-Up (durability) Testing using neat diesel MTU-LHD + (MOD 5) cycle.

2. Ignition Temperature Testing with neat diesel.

3. Gaseous and Particulate Emission Testing.

4. Sulphate and Ames Testing.

5. Ignition Temperature Testing using 45 mg Ce/L diesel.

6. Ignition Temperature Testing using 90 mg Ce/L diesel.

7. Ignition Temperature Testing using 80 mg Mn/L diesel.

8. Ignition Temperature Testing using 60 Mn/L diesel.

9. Exhaust Backpressure Build-Up (durability) Testing using 90 mg Ce/L diesel + MTU-LHD (MOD 5) cycle.

10. Particulate and Gaseous Emissions Testing.

11. Cerium Pass Through Testing.

12. Ames + Sulphate Testing.

13. Remove POT II.

14. Baseline Line Cerium Pass Through Testing.

15. Baseline Line Gaseous Emission Testing.

16. Baseline Line Particulate + Ames Testing.

3. TEST EQUIPMENT AND METHODOLOGY

All testing was conducted using a Deutz F8L 413 F/W engine installed in Cell #5 of the Ontario Research Foundation Dynamic Dynamometer Engine and Emission Testing Facility. The following sub-sections describe some of the equipment used and sampling procedure.

3.1 Dynamic Dynamometer Test Cell

The test cell is equipped with dynamometer, throttle activator and computer that enables the test engine to follow pre-determined speed and load schedule (no motoring).

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3.1.1 Dynamometer

An Eaton Model AO-8121 eddy current dynamometer is used in test cell #5 to absorb the power generated by the engine. This dyno is a wet gap type capable of absorbing 373 kW at 5000 RPM and has an inertia of 46 lb. ft^2. Torque is measured using a Lebow load cell connected to the trunnion mounted dynamometer casing. The dynamometer operation can also be manually controlled in a speed or torque mode via a stand-alone dyno exitation controller. Dynamometer bearing lubrication is provided by gravity fed oil reservoirs. A Hayes-Dana driveshaft with rubber element absorption is used as a coupling between engine and dyno.

3.1.2 Computer Control System

The heart of the dynamic test facility lies in the computer control system. This system uses a Hewlett Packard 1000 series E computer with 128K of memory and is coupled with a HP disc drive unit. Input/output interface is performed with Computer Products I/O equipment.

All programs are stored on a HP 7900 disc unit with measured and calculated data displayed on the operator console. The console is also used for entering operation commands concerning the test cell. During automatic control the system reads engine speed and torque ten times per second and, if required, corrects via output signals ten times per second. The system has a programming capability for cycle testing known as the schedule builder. The schedule builder is based upon a series of

steps. A step is a defined RPM, torque, ramp time, stay time, where ramp time is the length of time to change from one load speed condition to the next. Stay time is defined as the length of time to remain at a given load speed. The minimum ramp time is one second and the minimum stay time is zero seconds. Up to 198 steps are user definable, however, the system includes the capability of major and minor looping within a cycle.

3.2 Heavy Duty Diesel Emissions Test Facility

The sampling and measurement of diesel exhaust emissions has presented many problems with respect to obtaining representative data that will correlate to conditions that occur in the underground mining environment. Chemical and physical reactions with certain species of diesel exhaust emissions take place after the exhaust has been released from the engine exhaust system. Specifically, particulate agglomeration in the soluble and insoluble form occur as the exhaust temperature is lowered to promote condensation of the soluble organic material. Formation of nitrogen dioxide (NO_2) from nitric acid (NO) is a characteristic reaction in diesel exhaust as often it is released from the exhaust system. These reactions have necessitated the need for a representative diesel exhaust sampling and analysis system. EPA has standardized such a system for engine certification procedures.

In an effort to keep abreast of these changes, ORF has installed and commissioned a heavy duty diesel emissions test facility. The primary purpose of this facility is the measurement of emissions from diesel engines which are part of the dynamic test facility.

The facility is comprised of two major systems; the dilution tunnel system and the analytical system. The following sub-sections describe these systems.

3.2.1 Dilution Tunnel System

There are basically two types of dilution tunnels available for the sampling of diesel exhaust emissions. One uses a single dilution method, the other a double dilution. ORF has selected a double dilution tunnel from a flexibility and cost standpoint. With a double dilution system the primary air mover can be down-sized considerably to meet the temperature criteria necessary in designing such a system. The system comprises of three basic sections as described below.

3.2.1.1 Dilution Tunnel

The dilution tunnel consists of 25.4 cm inside diameter primary tunnel and a 10.2 cm inside diameter secondary tunnel. All tunnel components are fabricated of stainless steel. Engine exhaust enters the primary tunnel via an upstream facing 10.2 cm nozzle. Dilution air flows past the nozzle and the resultant counter-current flow enhances mixing of the exhaust with the air. The primary tunnel has been engineered to provide a Reynolds number of more than 4000 to provide sufficient turbulence of the diluted exhaust. A fine mesh screen prevents large foreign objects from entering the primary tunnel.

Three sample probes are located approximately 2.5 meters downstream of the exhaust inlet. The first probe is used to transfer a portion of the primary tunnel exhaust to the secondary tunnel. The second probe is used for sample transport to the heated hydrocarbon analyzer and the third probe is dedicated to the other gaseous analyzers. Maximum allowable primary tunnel gas temperature at the sample probes is 190°C. A specially designed acoustic chamber was installed at the primary tunnel inlet to minimize engine exhaust and air mover noise in the vicinity of the test facility.

The secondary tunnel can be used to further dilute the sample from the primary tunnel to maintain a sample filter that will not exceed the maximum allowable 52°C. Three sample filters and one bypass filter are connected to the outlet of the secondary tunnel. The filter holders accept 70 mm diameter filters (Pallflex T60A20) and produce a 60 mm diameter stain area.

Secondary, or back-up filters, are used to remove any particulate material that has passed the primary filter. Any one of the four filters can be selected manually or automatically from the particulate console. Automatic sequencing of the filter is achieved using computer activated relays or using a programmable sequence timer.

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The particulate console, contains an air pump and protective filters for sampling diluted exhaust. A second pump is used to provide pre-filtered air to the secondary tunnel when further dilution is required. Mass flows of sample gas and secondary dilution air are measured and controlled using mass flow controllers (Tylan Model FC202). These controllers are state-of-the-art devices which continuously monitor and correct the mass flow to maintain a proportional sampling rate, regardless of gas temperature and pressure. Accumulated dilution and sample gas flows are displayed using integrators, one set for each of the sample filters. The particulate console also contains a temperature measuring device to allow for recording of a variety of temperature stations, especially the primary and secondary tunnel gas temperatures.

Not for Distribution

3.2.1.2 Heat Exchanger

According to EPA specifications, the primary tunnel gas temperature must be adjusted to 43°C in order to provide constant gas density conditions to the primary air mover. In order to achieve a 147°C gas temperature drop, a tube and shell heat exchanger is located between the primary dilution tunnel and air mover. A 227 l pm water pump recirculates water through the shell side of the heat exchanger while primary tunnel exhaust gas is passed through the tube side.

During testing of duty cycles with high load factors, the primary tunnel gas temperature is well above 43°C. In these cases the heat exchanger is used solely to cool the gas and this is achieved by adding cold water to the recirculating water loop. Thermostatically controlled, air actuated, water valves allow water to enter the system and a check valve discharges an equal volume of warm water. A second heat exchanger which is steam heated can be used to raise the water temperature to 43°C (in the case of low load factor duty cycles).

3.2.1.3 Air Mover

The primary tunnel gas flow is normally maintained at 51.0 standard cubic meters per minute (SCMM) with a high capacity positive displacement blower. This blower is a roots type and uses a 22 kW electric motor as a drive. Excessive noise, characteristics of these blowers, is reduced using a Donaldson muffler.

3.2.2 Gas Analysis

The gas analysis system is comprised of a hydrocarbon console and a main analysis console. Filters, housed in the heated hydrocarbon console, are used to remove particulate matter from the sample gas stream. A Beckman, Model 402, heated hydrocarbon analyzer continuously measures gaseous hydrocarbons (as methane) at a temperature of 190°C using a flame ionization detector. Background

(ambient air) hydrocarbon concentrations are determined by sampling the dilution air at the primary tunnel. Concentrations of hydrocarbons in the dilution air are subtracted from the primary tunnel concentration to obtain hydrocarbon concentrations that are attributable to engine exhaust.

The main analysis console contains the NO, CO, CO_2 and heated NO_x analyzers. Four sample pumps are used to provide sample gas to the various analyzers. The following analyzers are used:

NO_x-Beckman Model 955 heated chemiluminescent analyzer

NO -Beckman Model 951A chemiluminescent analyzer

CO -Beckman Model 867 non-dispersive infra-red.

CO_2-Beckman Model 864 non-dispersive infra-red.

CO_2-Horiba Model A1A-21-AS non-dispersive infra-red.

Three calibration gases are used to span each analyzer for a given concentration range. These gases can be selected by push buttons on the main analysis console front panel. Strip chart recorders are used to display analyzer outputs on a continuous basis. Heated lines are used to keep the sample temperature well above the gas dewpoint to minimize losses due to condensation. A Hankinson dryer is used to remove sample gas moisture prior to the NO, CO and CO_2

analyzers. Air/water heat exchangers are used to remove sample gas moisture prior to the CO_2 analyzers.

Recent additions to the HP 1000 computer software now provide the capability of recording all gaseous emissions data for steady state and cycle testing. The computer provides a printout of gaseous pollutant mass emissions and exhaust flows and can average results over a transient engine operating cycle.

3.2.3 Particulate Analysis

The filters taken from the secondary dilution tunnel are conditioned for ≃ 12 hours and weighed. Then they are extracted for 8 hours using methelyene chloride. After reconditioning the weight of the filter is taken. The difference between the total weight and the weight after extraction is the soluble particulate material. The remaining material is the insoluble fraction.

3.2.4 Sulphate Sampling and Analysis

Samples were taken using the controlled condensation method. This system allows for the quantitative collection of sulphate $SO_4^=$ and sulphur dioxide (SO_2) from hot exhaust gas streams. The sampling system withdraws diluted exhaust gas through a glass probe maintained at 250°C for raw exhaust and 100°C for diluted exhaust. Next the exhaust passes through a glass cooling coil maintained at 70°C. The sulphate fraction is removed by the coil. Sulphur dioxide is removed by a following set of impingers

containing a 3% (V/V) hydrogen peroxide solution. Solutions are then reacted with barium chloride to form a barium sulphate suspension. The absorbance is measured with a spectrophotometer to determine the sulphur concentrations.

3.2.5 Ames Sampling and Analysis

A portion of the diesel exhaust is diverted through a heated sampling probe into a dilution tube. A calibrated high volume sampler is used as the primary air mover. The diesel exhaust mixes with ambient air and is passed through a 25 x 20 cm teflon coated glass fibre filter. A dilution ratio of ≈16:1 is achieved by controlling the sample blower speed with a variable power supply. Filters are then extracted for 16 hours with dichloromethane. The extraction solvent is then taken to dryness and the weight of the soluble organic fractions (SOF) determined. Each SOF sample is dissolved in dimethyl sulfur/oxide at a concentration of 10,000 mg/mℓ.

In this program the samples were tested with Salmonella tester strains TA-98 without metabolic activation over a concentration range of 10 to 600 mg per plate.

3.2.6 Fuel Additive Passthrough Analysis

Samples were taken from the dilution tunnel using a modified EPA Method 5 sampling trains. Samples were drawn through a glass-lined probe heated to 100°C and then

through a 125 mm teflon-coated glass fibre filter. Two impingers containing 5% nitric acid solution act as back-ups to the filter.

The probe, impingers and connecting glassware are rinsed using 5% nitric acid to make up the impinger sample.

Impinger solutions are analyzed by DC plasma emissions spectrophotometry with no further treatment. One quarter of each filter is heated with concentrated nitric acid. The solubles were then diluted to volume for analysis by DC plasma emissions. For both solutions, silver was analyzed separately using Flame Atomic Absorption.

An aliquot of each oil sample is ashed and dissolved in concentrated aqua regia to volume for analysis by DC plasma emissions. An aliquot of each fuel sample is digested with concentrated nitric and sulphuric acids again for analysis by DC plasma emissions.

3.3 MTU-LHD (MOD 5) Cycle

The cycle used in this program was the MTU-LHD (MOD 5) Cycle. The torque portion of the original Michigan Technological University MTU-LHD cycle has been increased. The modified cycle better represents a hotter LHD cycle. Figures 1 to 3 show typical traces of torque, speed and exhaust temperature for the MTU-LHD (MOD 5) Cycle.

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3.4 Fuel and Fuel Additive

Diesel 20X was used as test fuel during all the testing. Table - summarizes the physical property of the fuel.

The manganese fuel additive used was stock #8220 supplied by Lubrizol. The stock contains 39.6 mg of manganese per ml of additive.

The cerium fuel additive used stock #67394B also supplied by Lubrizol. The stock contains 39.3 mg of cerium per ml of fuel additive.

The appropriate amount of fuel additive was added to a drum of diesel (210L). A sample calculation is shown in Table - . The diesel fuel with additive was mixed mechanically before testing began.

4. DATA ANALYSIS

4.1 Ignition Temperatures

Ignition temperature is defined as the temperature and engine conditions at which the particulate material is being deposited and burnt off the particulate trap. This condition is determined by observing changes in the pressure differential across the traps.

In this program, particulate matter was first built up on the traps by operating the engine at 2200 rpm/180 N.m. until a ΔP of $\simeq$5-6 KPa was obtained. This engine condition is used because with an exhaust temperature of 270^{o}C it ensures that no partial regeneration takes place within the traps.

Once the traps were loaded up, the engine load was increased in increments of 25 N.m. Differential pressure was then measured until a significant trend was observed.

The test data is summarized in Figures to . Analysis of ignition temperature was done using these graphs and is summarized in Table I. Here it can be observed that ignition temperatures were significantly different between banks. This is probably due to different particulate characteristics between the banks of the engine.

The first test was performed on neat diesel fuel in case the fuel additives had a permanent effect on the CTOs. As shown in Table I, on neat diesel ignition, temperatures were 450°C and 420°C for the right and left banks respectively. With both treatment concentrations of cerium there was no significant improvement. Manganese additive did cause a small improvement in ignition temperatures to 420°C and 405°C.

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COMPARISON OF DIESEL FUEL

	*Phillips D-2 Lot G-075	Typical Gulf Diesel 40
Cetane Number	46.2	47
Distillation Range, °C		
IBP	191	173
10% Point	222	191
50% Point	263	223
90% Point	314	267
End Point	345	295
Gravity, °API	35.2	40.0
Total Sulphur, wt. %	0.35	0.16
Aromatics (FID), vol. %	32.1	N.A.
Kinematic Viscosity, cs	2.52	N.A.
Flash Point (PM), oC	72	63
Particulate Matter, mg/L	2.1	N.A.
Element Analysis, wt.%		
C	85.12	86.57
H	12.92	13.09
N	0.08	N.A.
O	0.06	N.A.
C/H	6.66	6.61

* 30.0 ptb of DuPont FOA #11 antioxidant enhances the stability of this fuel.

TABLE : Property of Diesel 20X
July, 1985.

% C	-	86.51
H	-	13.14
S	-	.31

IBP	- 189	^{o}C
80%	- 269	^{o}C
90%	- 304	^{o}C
95%	- 313	^{o}C
FBP	- 324	^{o}C

TABLE - : Sample Calculation of Fuel Additive in 210 L of Diesel Fuel.

To achieve 40 mg ce/L Diesel

$$45 \frac{\text{mg Ce}}{\text{L Diesel}} + \frac{\text{210 L Diesel}}{\text{39.3 mg/Ce/ml}}$$

= 240.45 ml of fuel additive.

24-Oct-85 FILE : IGNTEMP

Table I
Ignition Temperatures for POT # 2 (C)
2200 RPM (+ or - 5 degrees C)

	Right Bank	Left Bank	Torque (N.m)
Neat Diesel	453	430	400
45 mg Ce /L diesel	450	429	400
90 mg Ce /L diesel	450	423	400
60 mg Mn /L diesel	435	405	380
80 mg Mn /L diesel	420	404	375

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23-Aug-85 FILE : buildup

Table II
Average Backpressure Exhaust Build-up Rate (Kpa/hr)

2200 rpm, 180 N.m

	Right Bank	Left Bank
Neat Diesel	0.62	1.12
45 mg Ce /L diesel	0.89	1.26
90 mg Ce /L diesel	0.74	1.37
60 mg Mn /L diesel	0.68	1.39
80 mg Mn /L diesel	0.78	1.22

MTU-LHD Cycle (Mod 5)

	Right Bank	Left Bank
Neat Diesel	0.26	0.40
90 mg Ce /L diesel	0.14	0.41

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